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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, SKUNK RIVER BASIN, IOWA

Federal Water Pollution Control Administration
Kansas City, Missouri

August 1966

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY SKUNK RIVER BASIN IOWA

Study of the Needs and Value of Storage for Municipal and Industrial Water Supply and Water Quality Control

UNITED STATES
DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Kansas City, Missouri

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY
SKUNK RIVER BASIN
IOWA

A survey has been made which discloses a future need for municipal and industrial water supplies and a future need for storage for streamflow regulation for the purpose of water quality control. These conclusions are based on results of economic and demographic studies. Future needs are based on projected population and industrial growth.

Prepared for
DEPARTMENT OF THE ARMY
U. S. Army Engineer District
Rock Island, Illinois

U. S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Kansas City, Missouri
August 1966

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	iv
I. INTRODUCTION	
Authority	I-1
Purpose and Scope	I-1
Acknowledgements	I-2
II. SUMMARY OF FINDINGS AND CONCLUSIONS	
Findings	II-1
Conclusions	II-2
III. PROJECT DESCRIPTION	
IV. STUDY AREA DESCRIPTION	
Location and Boundaries	IV-1
Climate	IV-2
Principal Cities and Industries	IV-2
V. WATER RESOURCES OF THE STUDY AREA	
Quantity of Water Available	V-1
VI. THE ECONOMY	
Past and Present	VI-1
Future	VI-3

TABLE OF CONTENTS (Cont'd)

		Page
VII.	WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL	
	Present Water Uses and Sources	VII-1
	Future Municipal and Industrial Water Requirements	VII-2
VIII.	WATER QUALITY CONTROL	
	General	VIII-1
	Municipal and Industrial Pollution	VIII-1
	Water Quality Criteria	VIII-2
	Flow Regulation	VIII-2
IX.	BENEFITS	
	Municipal and Industrial Water Supplies	IX-1
	Water Quality	IX-1
	BIBLIOGRAPHY	
	APPENDIX	

LIST OF TABLES

No.	Title	Page
V-1	Mean Flow, Standard Deviation and Skewness of Flows at Ames	V-1
VI-1	Historical Employment Data by Major Categories	VI-5
VI-2	Agricultural Data	VI-5
VI-3	Manufacturing Employment	VI-6
VI-4	Manufacturing Trends	VI-6
VI-5	Historical Population Data	VI-7
VI-6	Population Projections	VI-7
VII-1	Future Municipal and Industrial Requirements (MGD)	VII-3
VIII-1	Minimum Streamflow for Quality Control	VIII-4
4-1	July Dilution Requirements Under Different Conditions	1 (App. 4)

LIST OF FIGURES

		Following
Figure 1	Location Map	App. 6
Figure 2	Schematic Drawing	VIII-2
Figure 3	Flow Frequency in the Skunk River at Ames - Fall and Winter	V-2
Figure 4	Flow Frequency in the Skunk River at Ames - Spring and Summer	V-2
Figure 5	Comparison of Available Flow with Flow Needed to Maintain Desired Quality	VIII-3
Figure 6	Monthly Flow Requirements to Maintain Desired Quality	VIII-3
Figure 7	Theoretical Monthly Drafts-on-Storage Required to Maintain Desired Quality	VIII-4

Figure 8	Probability of Annual Drafts-on-Storage to Maintain Desired Quality	VIII-4
Figure 4-1	Quality Expected Without Flow Augmentation - 1970 Conditions	App. 4
Figure 4-2	Quality Expected Without Flow Augmentation - 2070 Conditions	App. 4
Figure 4-3	Dilution Flow Requirements For July for Different Water Quality	App. 4
Figure 5-1	Protection Level (% of Years of Non-failure) Year 1970 Condition	App. 5
Figure 5-2	Protection Level (% of Years of Non-failure) Year 2020 Condition	App. 5
Figure 5-3	Protection Level (% of Years of Non-failure) Year 2070 Condition	App. 5
Figure 5-4	Annual Supplemental Flow In Volume for a 90% Probability of Assurance	App. 5
Figure 5-5	Water Quality at Different Probability Levels Resulting from 5000 Acre-Feet of Supplementary Flow	App. 5
Figure 5-6	Theoretical Average Monthly Reservoir Levels	App. 5
Figure 6-1	Benefit vs. Quality	App. 6

I. INTRODUCTION

Authority

The Corps of Engineers, U. S. Army Engineer District, Rock Island, Illinois, in a letter dated July 15, 1965, requested the Public Health Service,* Region VI, Kansas City, Missouri, to make a study of water supply and water quality control needs in the Skunk River Basin in connection with the proposed Ames and Gilbert Reservoirs. This study has been made in accordance with a Memorandum of Agreement dated November 4, 1958, between the Department of the Army and the Department of Health, Education and Welfare relative to the Water Supply Act of 1958, as amended (43 U.S.C. 390b) and the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.).

Purpose and Scope

The purpose of this study was to determine the present and future needs and value of municipal and industrial water supply and storage for water quality control on the Skunk River in the reaches affected by the proposed reservoirs. This includes parts of the following Iowa counties: Hamilton, Boone, Marshall, Polk, Jasper, Powshiek, Marion, Mahaska, Keokuk, Washington, Wapello, Jefferson, Henry, Lee and Des Moines.

The water requirements and the means and benefits (both tangible and intangible) of meeting those requirements have been investigated.

*Responsibility for water pollution control activities has been assigned to the Federal Water Pollution Control Administration by the Water Quality Control Act of 1965.

The scope of the study covers water storage needs during a one-hundred year study period, 1960 to 2060. The conclusions presented are tentative pending completion of a comprehensive water supply and water quality management study which will be conducted in this region by the Upper Mississippi River Basin Comprehensive Program for water supply and pollution control. The water quality flow requirements and values are suitable for project feasibility determinations.

Acknowledgments

The assistance and cooperation of State and Federal agencies and individuals are gratefully acknowledged by the Federal Water Pollution Control Administration. Particular appreciation is expressed to the following for data and advice furnished by their staff members:

U. S. Army Engineers, Rock Island District Corps of Engineers, Rock Island, Illinois

Iowa State Health Department, Division of Public Health Engineering, Des Moines, Iowa

Iowa Natural Resources Council, Des Moines, Iowa

Iowa State University, Civil Engineering Department, Ames, Iowa

Iowa State University, Department of Economics and Sociology, Ames, Iowa

State University of Iowa, Department of Civil Engineering, Iowa City, Iowa

State University of Iowa, Agricultural Law Center, College of Law, Iowa City, Iowa

United States Geological Survey, Water Resources Division,
Iowa City, Iowa

United States Geological Survey, Ground Water Division, Iowa City,
Iowa

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Findings

1. The Corps of Engineers, Rock Island District, is investigating the feasibility of two reservoirs in the Skunk River. These reservoirs are located on the Skunk River and Squaw Creek immediately above Ames, Iowa. The primary purposes of the reservoirs are flood protection, recreation, municipal and industrial water supply and streamflow regulation for quality control.

2. This study encompasses the entire Skunk River Basin with special emphasis in the areas immediately adjacent to the Skunk River.

3. The largest community in the basin, and the only major one contiguous to the Skunk River, is Ames, Iowa, which had a 1960 population of 27,003. The population of the economic area was 250,000 in 1960 of which 160,000 were urban and 90,000 were rural.

4. Present average daily water use in the basin amounts to 27 million gallons per day (MGD) to supply a population of 202,313 or an average per capita use of approximately 135 gallons.

5. At all locations ground water can be found in four available aquifers. The quality of ground water varies depending both on location and the aquifer from which the water is withdrawn. Ground water suitable for most municipal and industrial uses after conventional treatment to remove hardness is available in one or more aquifers at each location in the basin.

6. Essentially all communities in the Basin with sewage collection systems provided secondary treatment. The exceptions are Ellsworth,

with no treatment, and the south plant of Sigourney with primary treatment. Wastes having population equivalents of 300 and 7 respectively, enter the stream at these communities.

Conclusions

1. The total population of the study area is estimated to grow from 202,313 persons in 1960 to 250,000 by 2020 and 300,000 by 2070. The rural population is expected to decrease from 94,266 persons in 1960 to 90,000 in 2020 to 80,000 in 2070.

2. Based on economic projections and projected per capita water use, the municipal and industrial water demand in the study area will increase to 38 mgd by 2020 and 60 mgd by 2070. Projections to the year 2070 indicate that storage to yield 10 mgd for municipal water supplies are needed in the proposed reservoirs.

3. The annual value of storage to supply projected municipal and industrial water needs is based upon the most likely alternative that would be used in the absence of the project. The most likely alternate was found to be a single purpose reservoir at the Ames Reservoir site. The time of first need is 2020. The value of storage at the proposed reservoir with 98 percent assurance for water supply purposes over the 100 year project life is $38,000 per year including operation and maintenance costs and based on a project completion date of 1970.

4. A draft-on-storage* of 8,000 acre-feet at the Ames Reservoir site is recommended for quality control by the year 2070. This storage

*In this report the terms draft-on storage and supplemental flow in volume are synonymous.

is needed in addition to provision of adequate treatment at the source. The year of first need for releases for quality control in the Skunk River is 1970.

5. Maintenance of satisfactory water quality by streamflow regulation in the Skunk River Basin will benefit the recreational use and esthetic enjoyment of the stream.

6. The annual value of the benefits resulting from provision of storage in Ames Reservoir to give a 90 percent assurance that water quality will be maintained in 2070 based on the cost of construction and operating of a single purpose reservoir, is $198,000 per year.

7. Because of the frequent observation that water from the lower depths of a reservoir is devoid of dissolved oxygen during certain times of the year, provision should be made for the installation of multiple level outlet structures or other means of assuring that releases of water are satisfactory in quality. Actual releases should be based on wastes discharged and observations of stream conditions.

III. PROJECT DESCRIPTION

The proposed Ames and Gilbert Reservoirs, as shown in Figure 1 in the Appendix, are located in central Iowa in the upper reaches of the Ames River Basin. The Gilbert Reservoir site is situated on Squaw Creek and the Ames Reservoir site on Skunk River. Each site is located approximately five miles upstream from the City of Ames.

The primary purppse of the Ames Reservoir is to provide for flood protection with a conservation pool which can be utilized for recreation, water supplies, and streamflow regulation for water quality control. The outlet works consist of a single conduit through the dam with the invert at elevation 900.0 feet mean sea level. The discharge through the conduit will be controlled by three gates located in the center of the dam at an expanded portion in the conduit. The flood control pool will be between elevation 968.0 and elevation 949. The reservoir storage available at elevation 949 is 33,400 acre-feet of which 25,000 acre-feet are for the conservation pool and the remaining 8,400 acre-feet are allocated to sedimentation. The spillway will have a crest elevation of 953.0 with five tainter gates, with top elevation at 969.0.

The Gilbert Reservoir, as the Ames Reservoir, will provide flood protection with a controlled outlet which could allow for streamflow regulation. The outlet works are similar to that of the Ames Reservoir. The crest elevations of the spillway, presently under consideration, range from 949.0 mean sea level to 956.0 above mean sea level. This

corresponds to a range of capacity of from 32,000 acre-feet to 56,000 acre-feet. The drawoff from both the reservoirs will be near the bottom of the reservoir at the toe of the dam.

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The entire Skunk River Basin was considered in this study. The Skunk River extends from near the center of the State to the Mississippi River (see Figure 1). It is bounded on the northeast by the Iowa-Cedar River Basin and on the west and southwest by the Des Moines River Basin. The basin has an overall length of 180 miles and a maximum width of almost 40 miles, with an average width of 24 miles. The total drainage area of the basin is 4,355 square miles.

The largest tributary stream is the North Skunk River which has a drainage area of 868 square miles. Other tributaries having a drainage area in excess of 200 square miles are Cedar Creek, and Crooked Creek.

The topography of the Skunk River Basin is a result of glacial activity and subsequent periods of erosion. The upper part of the basin above Ames is so flat that it is necessary to provide tile drains in order that the land may be used for agriculture. Further downstream in the counties of Polk, Jasper, Marion and Mahasha, the river passes through extensive flood plains that have a width of up to two miles and has a very winding channel. Below this reach the valley narrows to approximately a quarter or a mile in width.

The slope of the stream channel is moderate to low and tends to decrease downstream. It varies from 3 feet per mile between Ames and

Colfax to 1.3 feet per mile between the Mahaska-Keokuk county line to the mouth of the river. In the early 1900's, the channel was straightened somewhat between Ames and the Mahaska-Keokuk county line. 9/ This has helped to improve the waste assimilation capacity of this stretch by increasing stream velocities and eliminating stagnant pools.

Climate

The normal annual precipitation at Ames, Iowa, is 31 inches per year. Precipitation increases to 35 inches per year near the mouth of the river, and averages approximately 32.8 inches per year over the entire basin.

The average monthly temperature ranges from 20 degrees in January to more than 70 degrees in June, July and August. The highest average monthly temperature is approximately 76 degrees, which occurs in July.

Principal Cities and Industries

The principal cities in the study area are: Ames, Newton, and Oskaloosa. The population of the largest of the principal cities studied is Ames, with a population of 27,003. No heavy water-using industries are presently located in the basin.

V. WATER RESOURCES OF THE STUDY AREA

Quantity of Water Available

At the present time, all the runoff is uncontrolled. The proposed reservoirs will largely control the runoff above Ames. The mean monthly streamflows at Ames below the confluence of the Squaw Creek and Skunk River are shown in Table V-1. Also shown are the standard deviation and the coefficient of skewness of the flows.

Table V-1

Mean Flow, Standard Deviation and Skewness of the Flows at Ames
Historical Record of 33 Years

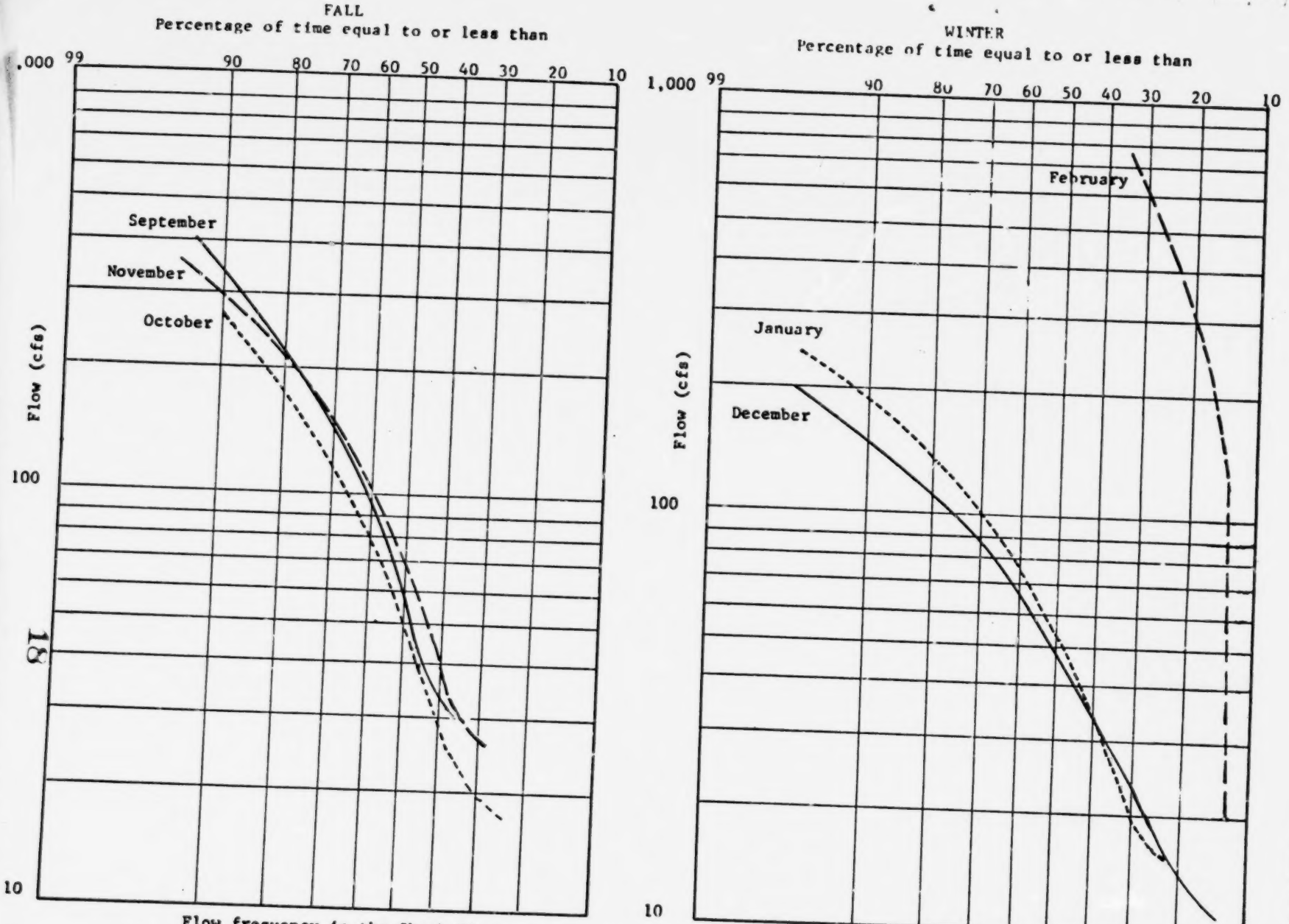
Month	Mean (cfs)	Standard Deviation (cfs)	Skewness
January	40	50	1.86
Feburary	84	76	.81
March	289	226	.49
April	206	252	2.33
May	252	239	1.92
June	315	385	2.41
July	155	174	1.79
August	65	93	1.86
September	66	118	2.85
October	49	72	1.90
November	57	84	2.45
December	35	41	1.09

The large standard deviations indicate that the flow is highly variable. The large skewness coefficients indicate that flow is not normally distributed but is affected by infrequent large flow values. The frequency of occurrence of the monthly flow is shown in Figures 3 and 4. For purposes of presentation, the figures are arranged to show the grouping of the months into four seasons.

Ames, the major point of need, has negligible uncontrolled flow. The total average flow in the basin, as measured at Augusta, Iowa, is 2,187 cfs.

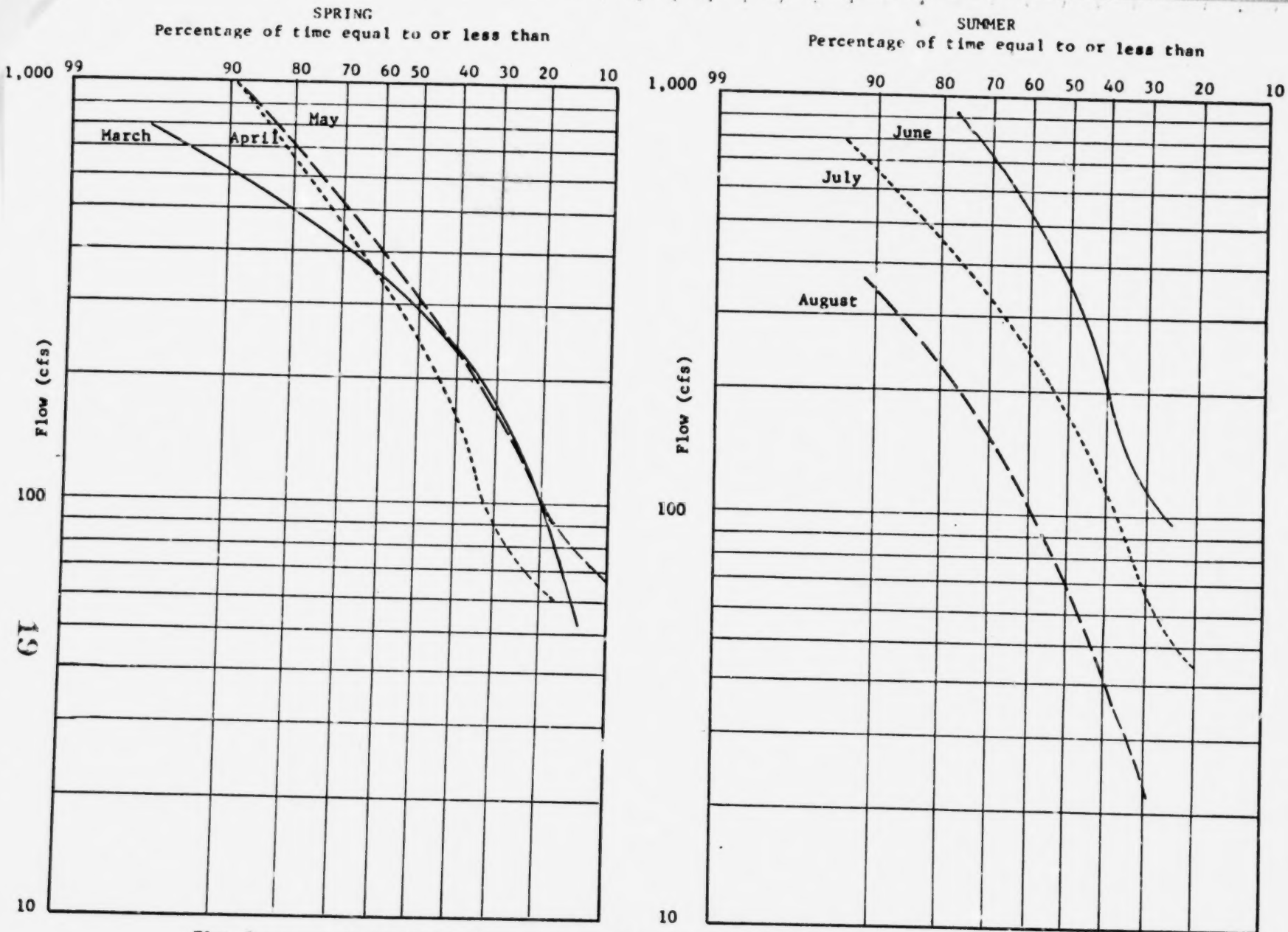
Ground water plays the most significant role in municipal water supplies. Essentially, all the communities in the basin draw their water from ground water sources. The exceptions are the cities of Fairfield, Oskaloosa, and Montezuma. Of these cities, Oskaloosa is the only community which draws water from the Skunk River. However, the municipality uses wells as its main source and the river as a standby source.

Ground water in the basin can be obtained from four different aquifers. These can be designated as follows: Surficial, Upper Bedrock, Middle Bedrock and Lower Bedrock. The surficial aquifer which is composed of the sand and gravel deposits on the surface of the bedrock is located immediately adjacent to the stream and is capable of yielding large supplies of water. It has rapid recharge properties. 14/ A study at Ames has shown direct correlation between the water table level and



Flow frequency in the Skunk River at Ames, Iowa below confluence of Squaw Creek

FIGURE 3



Flow frequency in the Skunk River at Ames, Iowa below confluence of Squaw Creek

FIGURE 4

the level of flow in the Skunk River. A higher water level in the stream will cause an increase in the elevation of the water table level. 16/

The yield from the upper and middle bedrock aquifers are usually much lower, being in the order of a 100 gallons per minute (gpm), as compared to 500 gpm from the surficial aquifer.

The yields from the lower bedrock aquifers are considerably higher. It is possible to obtain yields over 1,000 gpm. This aquifer is fairly deep, being in the order or a 1,000 feet or greater from the surface.

The quality of the water in the surficial aquifer is generally suitable for domestic use, with the possible exception of hardness, which is of the order of 300 ppm or greater, therefore, making softening necessary. The quality of the water from the upper aquifer is good in the upper part of the basin and poor in the lower reaches. The dissolved solids in the lower reaches vary between 500 ppm and 4,000 ppm.

The quality of the water in the middle bedrock aquifer is generally poor. The sulfates are well over 250 ppm and the dissolved solids are in the order of 1,000 ppm or more. Potable water is available in much of the lower bedrock aquifer. The sulfate content is usually 250 ppm or less and the hardness reaches up to 400 ppm. 14/ It can be readily softened by standard methods, however.

VI. THE ECONOMY

Economic and demographic studies in the Skunk River Basin are used as a basis for determining future municipal, industrial, and quality control water requirements.

The Skunk River study area includes the following Iowa counties: Story, Jasper, Mahaska, Keokuk, Jefferson, Henry and Des Moines. The major municipalities (over 5,000) and their 1960 populations are Mount Pleasant (7,339), Newton (15,381), Fairfield (8,054), Oskaloosa (11,053), and Ames (27,003).

The economic analysis and projections are based primarily on published information from Federal, State and local agencies.

Past and Present

The economy of the Skunk River study area is well diversified. In 1960, the labor force (80,143 employees) was well distributed among the normal employment categories, with sixty-one percent employed in the service category (including construction, transporation, communication, utilities, retail and wholesale trade, public administration, and personal services) and thirty-six percent employed in the basic categories (agriculture, mining, and manufacturing). The remaining three percent was unemployed. Refer to Table VI-1 for employment data by major classifications. 1/

The economic role played by agriculture in the study area is an

important one. Although employment in agriculture and the number of farms are declining, production (when measured by dollar output) has been steadily increasing.2/

Employment in this category has decreased from about 19,000 in 1950 to about 13,000 in 1960, while increased technological advances and farm consolidation have increased production from about 117 million dollars in 1954 to 157 million dollars in 1959 (adjusted to the 1958 value of the dollar). Refer to Table VI-2.1,2/

Mining contributes little to the economy of the study area, employing about 250 persons, and receiving about 2 million dollars annually (adjusted to the 1958 value of the dollar). The study area produces coal, stone, sand, and gravel and clays.3/

In 1960, the Skunk River study area had about 15 thousand persons employed in the manufacturing category. The number employed in this category has been increasing in actual number and in its proportion to the labor force since 1950. Employment increased from 11,318 in 1950 to 15,191 in 1960, representing 15 and 19 percent of the total labor force, respectively. Refer to Table VI-1 for employment data.1/

Fabricated metal, machinery, vehicle and food and kindred product categories have been the largest employer in the manufacturing category. Refer to Table VI-3.

Value added by manufacturers, generally considered the best value measure for comparing economic importance of manufacturing among industries, has shown a slight increase from 144 million dollars

in 1954 to 147 million dollars in 1958 (adjusted to the 1958 value of the dollar). Refer to Table VI-4.4/

The population of the study area increased about 17 percent from 1910 (172,873) to 1960 (202,313). During the same period the urban sector increased 100 percent from 53,997 to 108,047 while the rural sector decreased 20 percent from 118,876 to 94,266. The most dramatic change during this period came from Ames which increased from 4,223 to 27,003. Refer to Table VI-5.5/

Future

The economic and demographic projections are based strictly on a review of available information developed and presented by Iowa State University and the Iowa Development Commission. In general these projections have been developed on a State, Regional, and county basis and are dependent on an expanding State and National economy in which increasing amounts of goods and services are likely to be required to meet the needs of a growing population and higher standards of living.

Employment in agriculture is projected to remain relatively stable, decreasing slightly to 11 thousand in 2010 and to 10 thousand in 2060. Production is expected to increase about 100 percent by 2060.8/

Manufacturing is projected to continue its increase in the future to about 20 thousand in 2010 and 25 thousand in 2060, with the largest share in the fabricated metals and the food and kindred products categories.

Production in the food and kindred products category (which creates a significant demand for water) is projected to increase about 150 percent by 2060.7/

The population of the study area is expected to continue to grow, the total increasing from 202,313 in 1960 to 250,000 in 2010 and 300,000 in 2060. During this period the urban portion should increase from 108,047 to 160,000 to 220,000 while the rural portion should continue to decrease from 94,266 to 90,000 and to 80,000, respectively. Refer to Table VI-6. These projections were based on a study conducted by Iowa State University, titled, Projections of Iowa's Economy and People in 1974.6/

Table VI-1

Historical Employment Data
by Major Categories

Skunk River Basin
1950-1960 1/

	1950		1960	
	No.	Percent	No.	Percent
TOTAL BASIC	30,637	41	29,177	36
Farm	19,077	26	13,737	17
Mining	242	-	249	-
Manufacturing	11,318	15	15,191	19
TOTAL SERVICE	42,789	57	48,559	61
UNEMPLOYED	1,136	2	2,407	3
TOTAL LABOR FORCE	75,012	100	80,143	100

Table VI-2

Agricultural Data

Skunk River Study Area
1954-1959 2/

	No. Farms		(1000 Acres) Acres Cropland Hvred.		(Millions $)* Value of Farm Products Sold	
	1954	1959	1954	1959	1954	1959
STUDY AREA	13,977	12,442	12,589	11,188	117	157

*Adjusted to the 1958 value of the dollar.

Table VI-3

Manufacturing Employment

Skunk River Study Area
1950-1960[1/]

	1950		1960	
	Number Employed	Percent	Number Employed	Percent
MANUFACTURING	11,318	100	15,191	100
Furniture, Lumber & Wood Products	814	7	842	6
Fabricated Metals, Machinery, Vehicles, Other Durables	6,593	58	10,206	67
Food & Kindred Products	1,161	10	1,550	10
Printing & Publishing	698	6	1,117	8
Other Manufacturing	2,052	19	1,476	9

Table VI-4

Manufacturing Trends

Skunk River Study Area
1954-1958[4/]

	No. Estimated		Value Added by Mfg. ($1000)*		Capital Exp. ($1000)*	
	1954	1958	1954	1958	1954	1958
STUDY AREA	225	267	130,567	146,727	7,846	9,408

*Adjusted to the 1958 value of the dollar.

Table VI-5[5/]

Historical Population Data

Skunk River Study Area
1910-1960

	1910	1920	1930	1940	1950	1960
TOTAL	172,873	171,551	181,092	180,381	194,528	202,313
URBAN	53,997	61,488	72,194	74,609	93,263	108,047
RURAL	118,876	110,063	108,898	105,772	101,265	94,266

Table VI-6[6/]

Population Projections

Skunk River Study Area
2010-2060

	2010	2060
TOTAL	250,000	300,000
URBAN	160,000	220,000
RURAL	90,000	80,000

VII. WATER REQUIREMENTS, MUNICIPAL AND INDUSTRIAL

Present Water Uses and Sources

The present primary use of water in the basin is for municipal water supplies. Appendix 1 contains the communities and, where the information is available, it contains the amount of water used. The largest of the communities, Ames, had a daily water use ranging from about 2.2 mgd (million gallons per day) in January to 3.0 mgd in August. Mount Pleasant State Institution and Oskaloosa are the only institution and community which draw water from the Skunk River. Oskaloosa also maintains wells from which most of its supply is obtained.

Under Iowa law, each municipality which has increased its water use in excess of 100,000 gallons per day, or 3 percent per day more than its highest per day use prior to May 16, 1957, must obtain a permit for water use. A permit must also be obtained for individual use in excess of 5,000 gallons of water per day. Appendix 2 indicates the total amount of water which has been put under permit since 1957. It is emphasized that the municipal quantities do not indicate the total municipal demand since only those communities which have sufficiently increased their water use to require a permit are shown.

Except for its hardness, which is approximately 350 ppm as $CaCO_3$, the quality of the water in the Skunk River is suitable for municipal use. In contrast to this, the ground water varies between aquifers

as indicated before. However, water of suitable quality can be found in one of the aquifers. The water will be hard, but standard treatment can make it suitable for normal municipal use.

Future Municipal and Industrial Water Requirements

The results of the economic and demographic studies show a moderate increase in the population of the principal communities in the basin by 2060. The present per capita use of water for domestic purposes is about 65 gpd (gallons per day). In larger cities, domestic use per person may range as high as 85 gpd, whereas in communities of less than 500, it may be as low as 48 gpd. These are direct use figures that were calculated from water bills. The per capita use of water in municipalities is generally much greater, considering commercial and light industrial water uses. On this basis, the current per capita use, ordinarily supplied through municipal systems, is estimated to be about 135 gpd. 14/ For projections of future use, it is estimated that increased industrialization and increased standards of living will raise the per capita consumption to 150 gpd by 2020 and 200 gpd by 2070. Using these projections, the municipal needs by 2010 and 2070 for the major municipalities are shown on Table VII-1.

Table VII-1

Future Municipal and Industrial Requirements (MGD)

Skunk River Basin

	2020	2070
Ames	10	20
Other Municipalities	12	23

The total water use for the basin with the exception of steam electric power is projected to be 38 mgd in 2020 and 60 mgd in 2070.

All the communities, with the exception of Ames, have sufficient ground water available to handle their projected needs. Although quality of ground water varies between the four aquifers, water of suitable quality can be found in at least one of the four aquifers available.

The surficial aquifer from which Ames withdraws its supply has been estimated to have sustained yield of 10 mgd. The needs for Ames are projected to reach 20 mgd by 2070, thus requiring an additional water source. The Skunk River at Ames has periods of no flow and cannot be depended upon for supply without storage. Except for hardness, which is frequently as high as 325 ppm as $CaCO_3$, the water is suitable for municipal use. The water can be made suitable for normal municipal use by standard treatment.

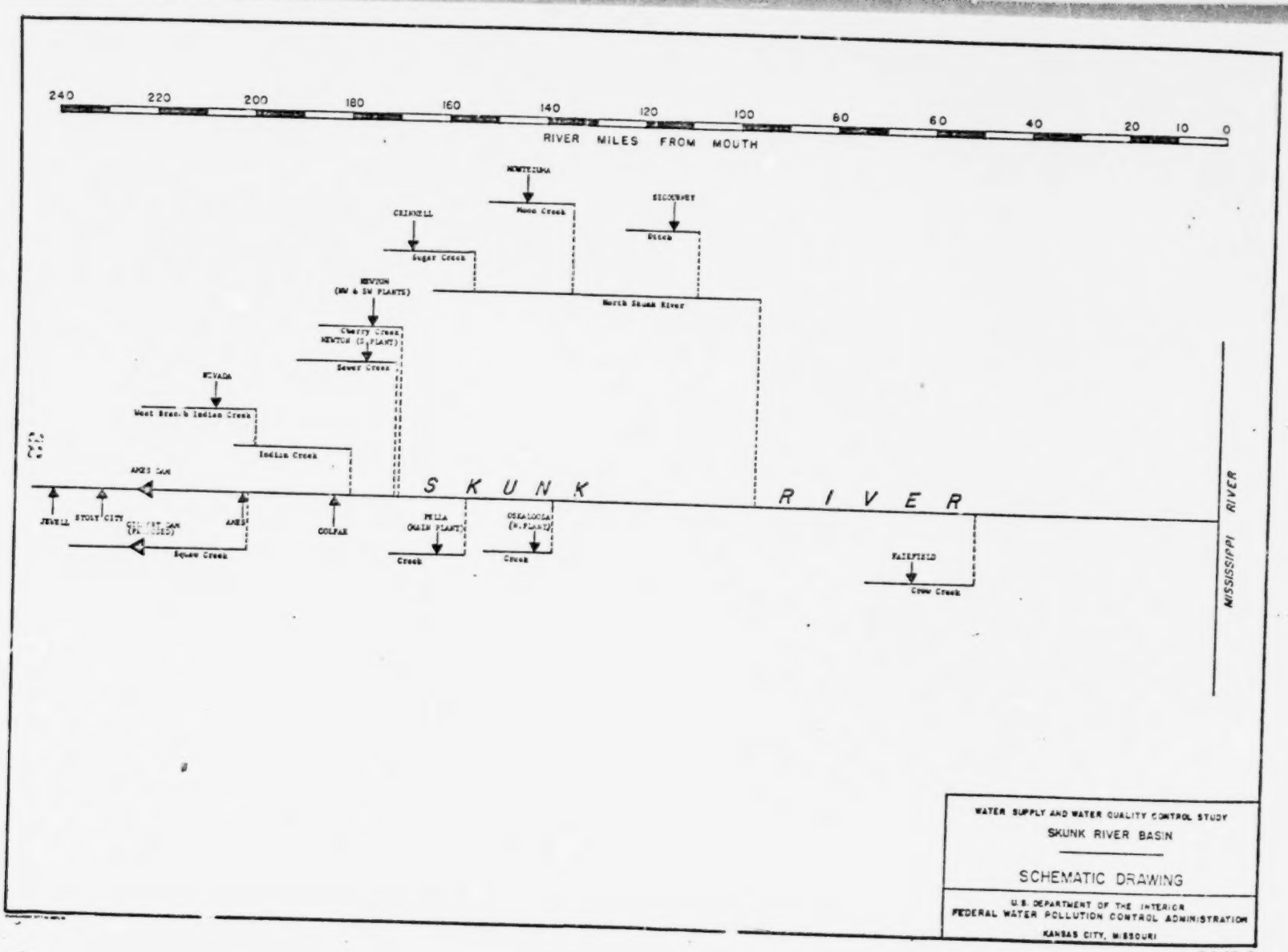
VIII. WATER QUALITY CONTROL

General

The use of water for municipal and industrial purposes will inevitably result in the production of liquid waste which, even after provision of levels of treatment considered adequate at this time, could degrade the quality of the receiving stream. It is essential that recognition be given to the facilities needed if the quality of the receiving streams are to be kept at acceptable levels. The potential of streamflow regulation to meet this need has been recognized in provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.) requiring consideration of the inclusion of storage in Federal reservoirs for regulation of streamflow for quality control in the survey of planning of a reservoir by any Federal agency. Section 3b of the Act expressly states that any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling waste at their source.

Municipal and Industrial Pollution

The municipalities with public sewer systems which discharge effluent into the streams in the basin are shown in Appendix 3. Figure 2 shows the location of the major communities which were



WATER SUPPLY AND WATER QUALITY CONTROL STUDY

SKUNK RIVER BASIN

SCHEMATIC DRAWING

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
KANSAS CITY, MISSOURI

FIGURE 2

considered in the analysis for water quality needs. The methodology used in determining these needs is shown in Appendix 4.

No industries discharging significant inorganic pollution are presently located or are projected to be located in the basin. At present, the stream is relatively free from inorganic pollution and no pollution of this type is foreseen in the future.

Water Quality Criteria

The major water uses in the basin have been discussed above. In addition, the permits which have been issued indicate that an important basin water use is recreation. A dissolved oxygen concentration of 5 ppm is recommended in order to maintain suitable conditions for the proliferation of fish life. This criterion is generally accepted by most governmental and other water pollution control and conservation agencies. The achieving of this goal will protect the Skunk River for other uses as well as recreation.

Flow Regulation

Provision of storage for streamflow regulation has been based on the provision of adequate treatment for all municipal and industrial wastes. Analysis of the effects of anticipated waste loads in the Skunk River indicates that two main oxygen sags will occur. One critical point occurs below Ames as a result of the effluent from Ames. The other occurs below the creek which carries the effluent from Newton and is due to the combined loads from upstream sources. By maintaining the required flows at Ames, the needs at Newton are also satisfied.

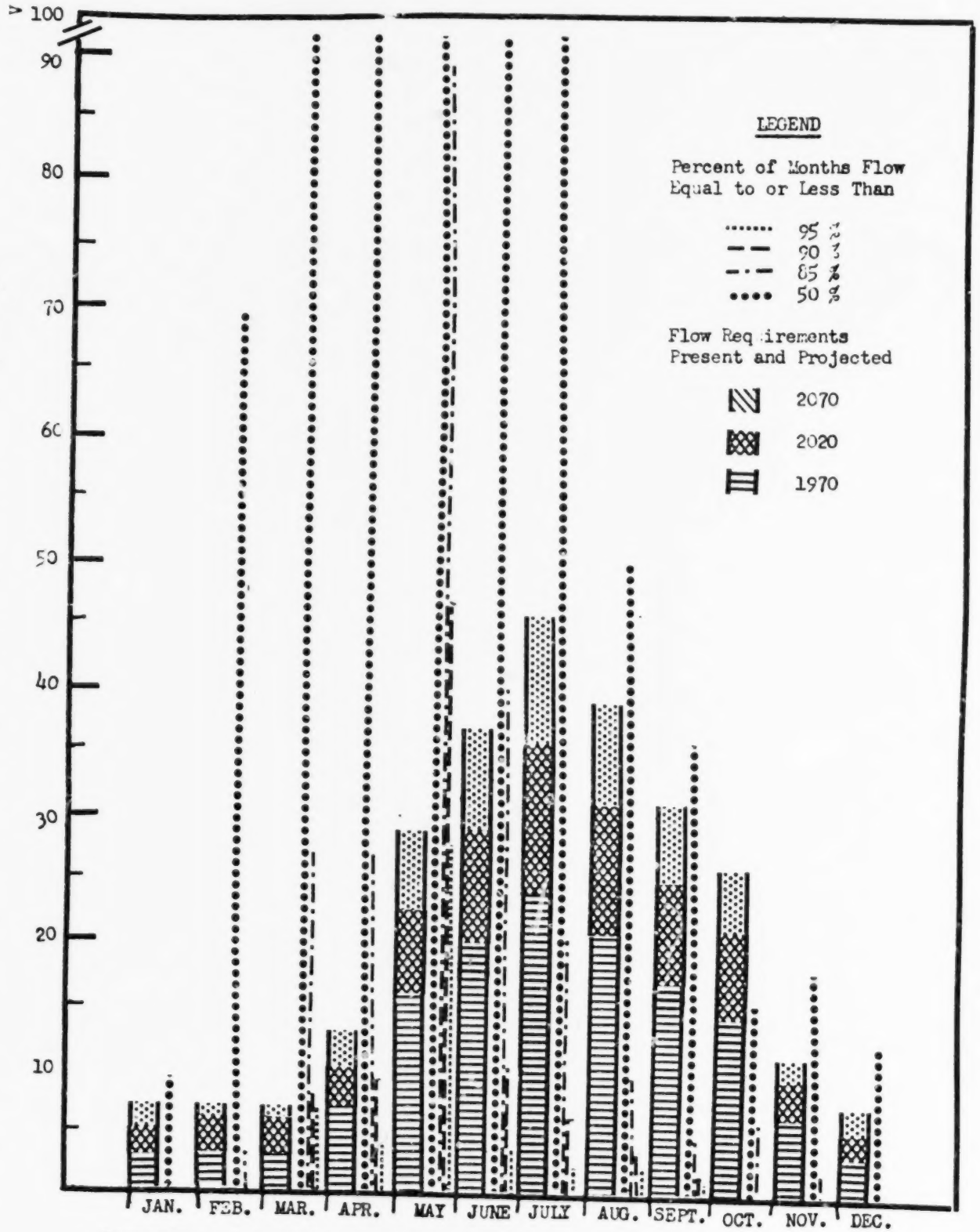
D.O. Concentration

Figure 5 shows the amount of flow required based on a 5 ppm/goal for different future projections along with the amount of flow available at different probability levels. Thus, in April, 90 percent of the time the flow was 9 cfs or larger and the present quality need is 7 cfs, therefore, no low flow augmentation benefit can be presently ascribed. However, by 2020 the flow requirement for quality control has increased to 10 cfs, thus, requiring low flow augmentation.

Flow needs were analyzed for each month. Most of the streamflow regulation for water quality control will occur during the summer months. Figure 6 shows the flows required for the recommended water quality level over the design period or 100 years for each month. These are minimum required streamflows above the sewage outlet from Ames, and include natural runoff as well as reservoir releases. They are theoretical requirements and the actual regulation of flow must be based on adequate water quality monitoring. As the communities develop and additional waste loads are encountered, the rate of flow must be increased accordingly.

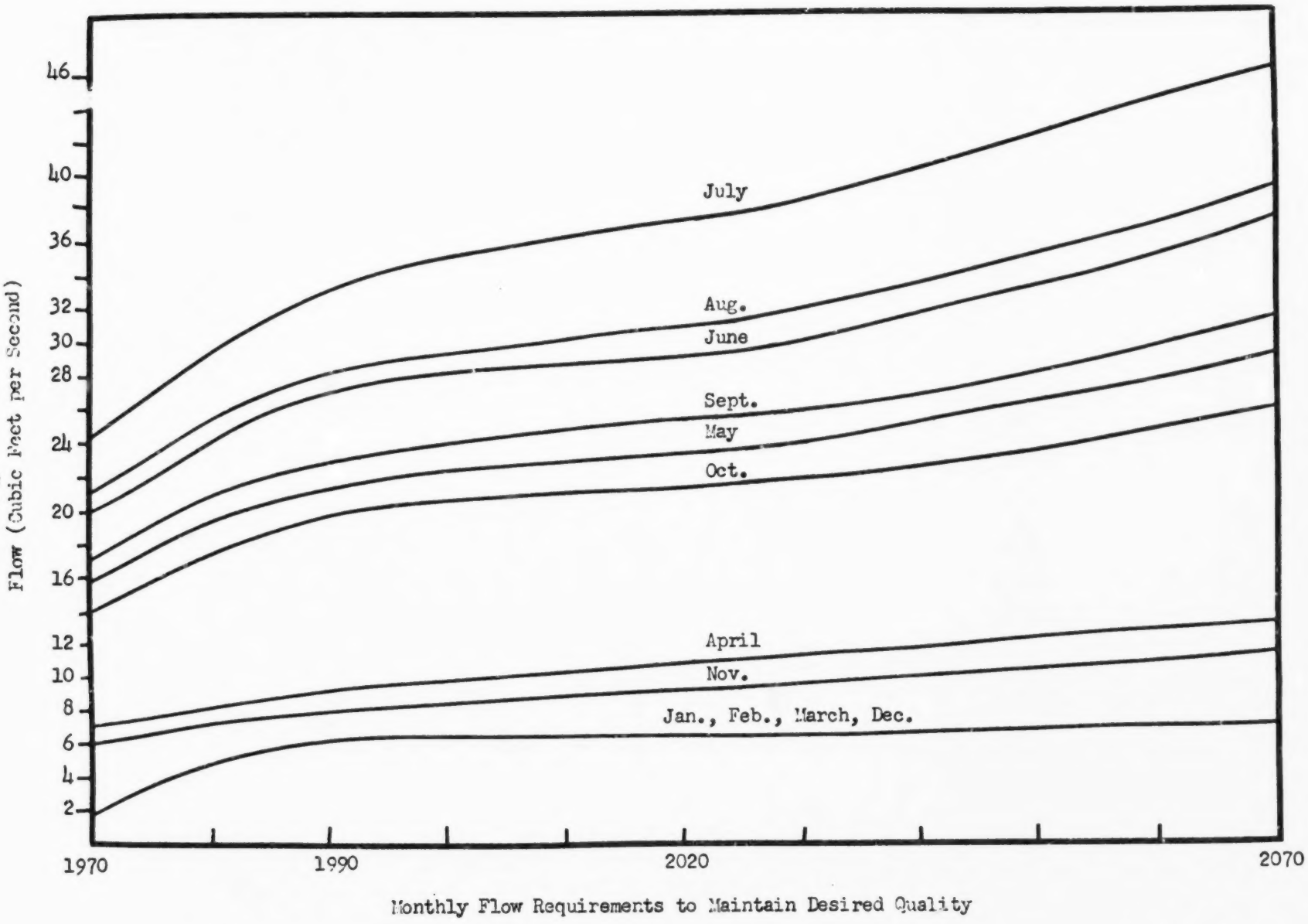
The required draft on storage was calculated by routing synthetically generated* monthly flows through a series of different sized reservoirs, neglecting the effect of evaporation, sediment storage and reservoir management. The result of this analysis is shown in Appendix 5.

*Synthetic flows were generated based on analysis of the monthly flow records available on the Skunk River, considering seasonal changes and serial correlation between succeeding seasons.



Comparison of Available Flow with Flow Needed to Maintain Desired Quality

FIGURE 5



Monthly Flow Requirements to Maintain Desired Quality

FIGURE 6

Figure 7 shows the draft on storage for the recommended quality level for each month and the range of variation is shown by plus and minus, one standard deviation. Therefore, 68 percent of the drafts will fall in this range. Figure 8 shows the probability of the sizes of drafts which can be expected. Thus, for the year 2020, 25 percent of the years the draft is equal to or less than 2,100 acre-feet, and for 50 percent of the years it is equal to or less than 3,300 acre-feet.

A total draft on storage of 8,000 acre-feet is recommended. This will provide a protection level of 90 percent of the years at the recommended quality level of 5 ppm. This is also indiciated by the dashed lines in Figures 5 -1, -2, -3 in Appendix 5. It may be noted in these figures that when a protection level of greater than 90 percent is desired the storage requirements increase quite rapidly.

With a storage for a supplemental flow of 8,000 acre-feet and routing 250 years of synthetically generated monthly flows, it was found that the monthly failures occur in the months of August through January. The average failure in these months is given in Table VIII-1.

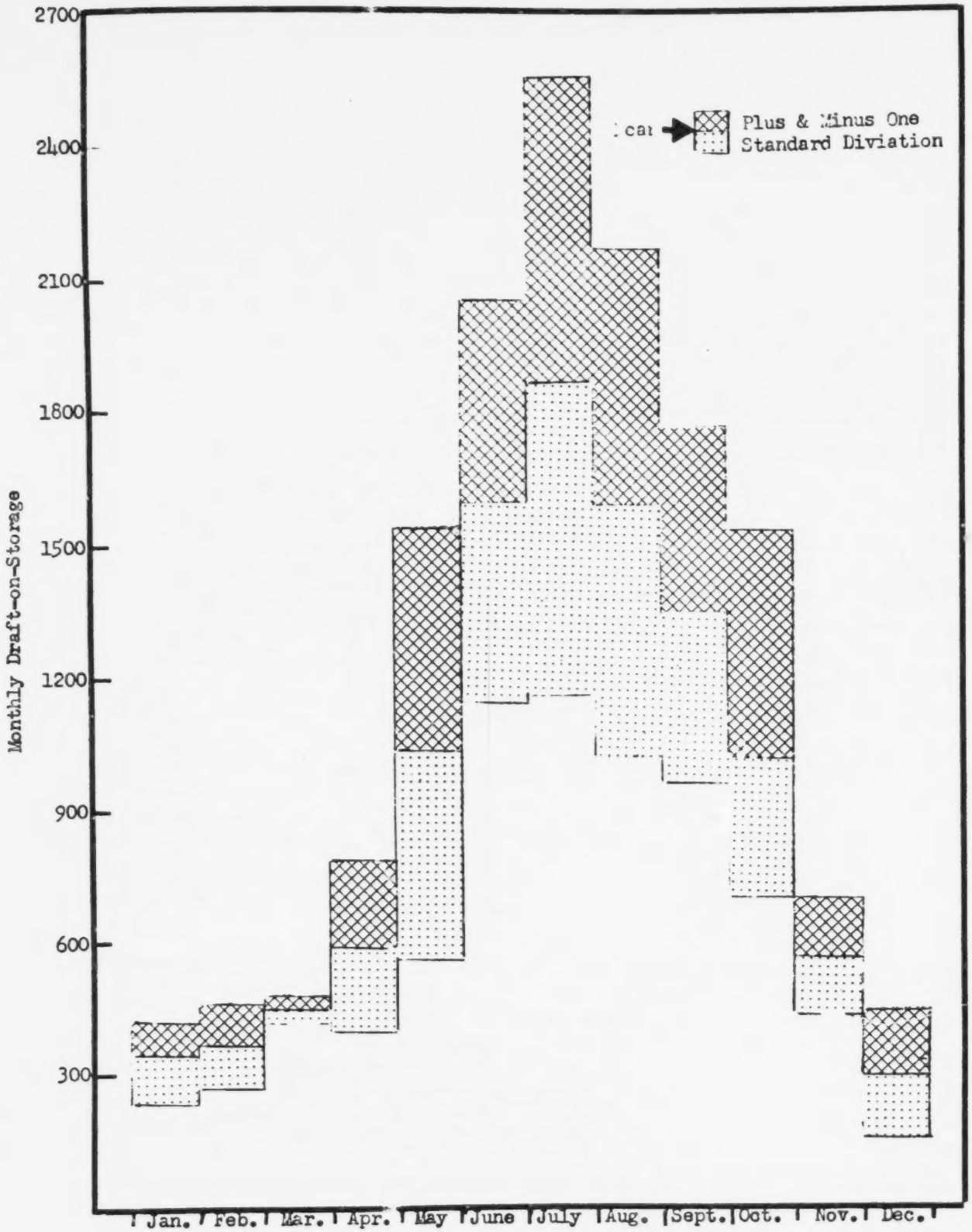
Table VIII-1

Monthly Failures

Months	Average Dilution Requirements Acre-Feet	Average Failure Acre-feet	Probability of Failure
August	2,690	518	2.4%
September	2,130	1,747	1.6
October	1,890	1,248	2.4
November	938	936	1.2
December	724	468	1.6
January	724	575	1.6

As can be seen, the magnitude of failures which do occur are quite substantial in all of the months except August. Therefore, in the months that do fail, based upon the operation scheme described, the dissolved oxygen would go to zero. However, under actual reservoir operation it would be possible to limit the releases in proceeding months when reservoir levels were dangerously low and thus, decrease the magnitude of failure. This would have the effect of increasing the number of failures, however, if the quality was allowed to go from 5 ppm to 4 ppm in the fall this would have little effect on fish life.

If the magnitude of failures were averaged over all months, they would average about 8 acre-feet per month in the year 2070 which would have negligible effect on water quality. However, as comparison



Theoritical Monthly Drafts-on-Storage Required to Maintain Desired Quality

In Year 2020

FIGURE 7

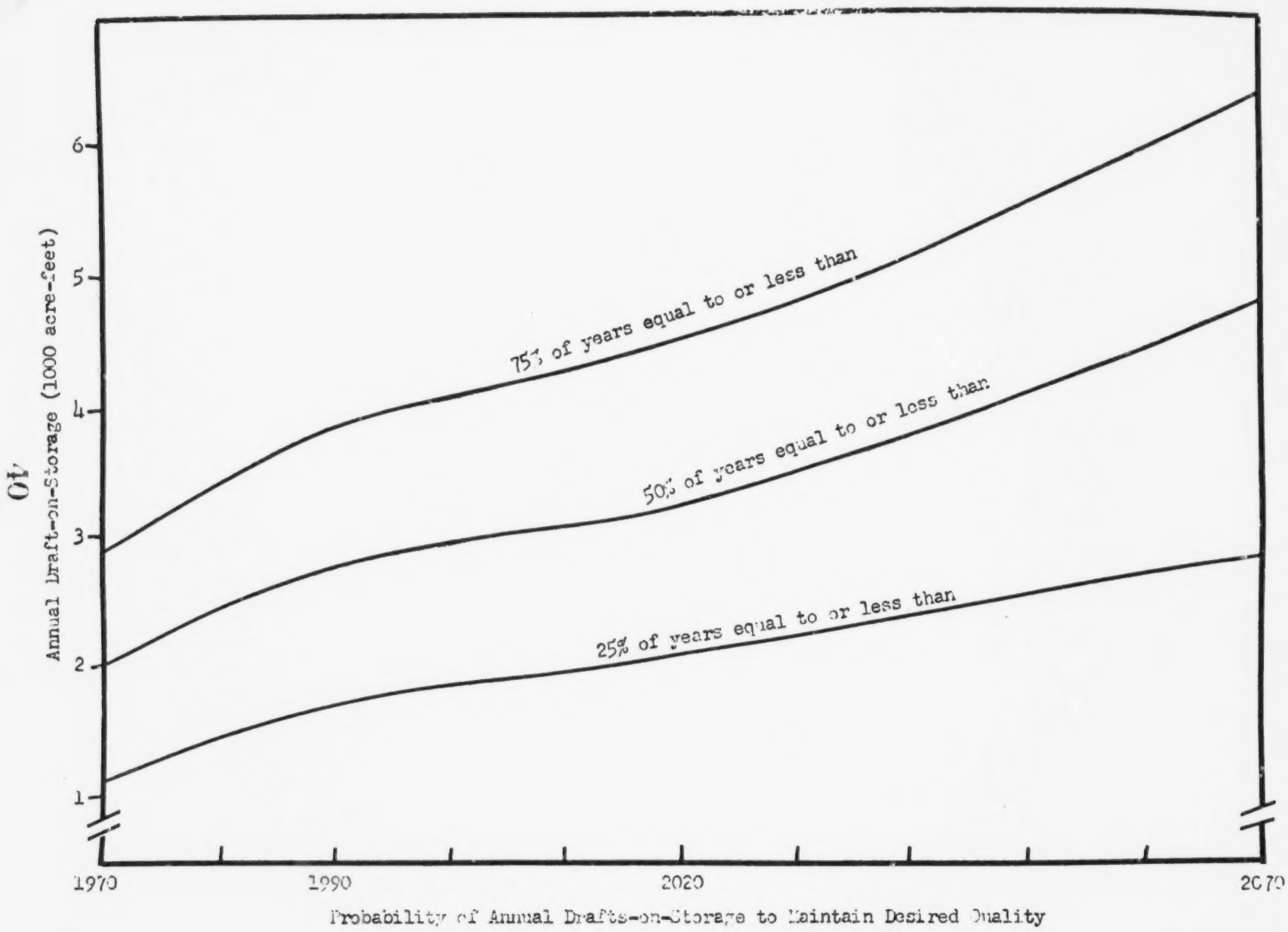

Annual Draft-on-Storage (1000 acre-feet)
6
5
4
3
2
1
75% of years equal to or less than
50% of years equal to or less than
25% of years equal to or less than
1970
1990
2020
2070
Probability of Annual Drafts-on-Storage to Maintain Desired Quality

FIGURE 8

a storage of 7,000 acre-feet would result in an average monthly failure of twice this or 16 acre-feet, even though it only reduces the probability of assurance of maintaining 5 ppm from 90 percent to 86 percent of the years.

The present proposed design of the outlet facilities calls for the water intake to be near the bottom of the reservoir. Stratification will result in the occurrence of low dissolved oxygen content in the lower depth of the reservoir in the summer months. A study on the Coralville Reservoir indicates that the oxygen content can drop to 1 to 3 ppm for long periods of time. In order to meet this problem, it is recommended that a multilevel intake or some other means of drawing off the better quality water near the surface be provided. Another method would be to provide for enough turbulence in the discharge water to assure uptake of oxygen to maintain at least 80 percent saturation.

IX. BENEFITS

Municipal and Industrial Water Supplies

The foreseeable need for additional water supply that could be supplied by storage in the proposed projects is limited to Ames, Iowa. The projected 2070 water supply needs at Ames will require a 10 mgd supply from a source other than the presently used aquifer. The most feasible alternate to supply this water is a single purpose reservoir at the Ames Reservoir site. The total cost of such a reservoir capable of supplying the anticipated needs is $4,682,000 with an annual operation and maintenance cost of $8,000.

The year of first need is 2020. Using an interest rate of 3-1/8 percent (the current Federal rate) to discount to 1970 and amortizing over a hundred years, the annual value of the benefits resulting from provision for water supply in the Ames Reservoir to meet anticipated 2060 needs is $38,000 per year.

Water Quality

The benefits to be derived from storage for streamflow regulation for water quality control may be tangible or intangible. The benefits that will result from storage in the Ames Reservoir are based on cost of the most economical alternative that will achieve comparable results.

An assured adequate water quality will provide favorable conditions for recreation, such as fishing, for those living in the Skunk River

Basin and nearby areas. It is reasonable to anticipate that the total population in the study area, plus the people located in the Des Moines metropolitan area, will be able to enjoy the recreational opportunities made possible by control of water quality.

In addition to recreational benefits, riparian property owners will enjoy improved esthetics of the stream stemming from unpolluted surface water and a satisfactory public health environment. From the above, it is concluded that benefits are widespread in scope and sufficient in magnitude to justify the provision of the volume of storage necessary for the required streamflow regulation. These benefits credited to storage for the regulation of streamflow for water quality control purposes are based on the premise that adequate treatment will be provided. Streamflow regulation for quality control, together with adequate treatment of municipal and industrial wastes will maintain the desired oxygen concentrations which will benefit the fishery by providing an optimum environment for growth. If streamflow regulation is not provided as recommended, recreation will suffer. By 2070, the critical areas in the river will have periods of zero oxygen content in which fish will not be able to survive even though waste treatment is provided to the fullest extent now practicable.

The value of benefits of storage for water quality control is approximated by calculating the cost of a single purpose reservoir with sufficient storage to yield a supplemental flow of 8000 acre-feet per year. Appendix 6 shows the analysis of benefit to quality control based on this premise. The single purpose reservoir would

be located above Ames, Iowa. The total cost of such a reservoir is $5,800,000. The year of first need is 1970. The annual operation and maintenance cost is $10,000, with an interest rate of 3-1/8 percent and amortized over a one hundred year period; the annual value of storage for flow regulation for water quality control is $198,000.

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Appendix 1

Municipal Water Supplies
in the Skunk River Basin

Community	Estimated Pop. Served	Source of Supply	Rated Plant Capacity MGD	Average Plant Output MGD
Ames	27,005	Deep Wells	2.100	X *
Batavia	535	Drilled Well	- **	X
Baxter	680	Drilled Well	.173	X
Blairsburg	285	Drilled Wells	-	X
Brighton	725	Drilled Well	.108	X
Cambridge	585	Drilled Well	X	X
Colfax	2,330	Gravel Packed Wells	X	X
Collins	435	Drilled Well	X	X
Colo	575	Drilled Wells	X	X
Crawfordsville	315	Drilled Wells	X	.015
Danville	580	Drilled Wells	X	X
Delta	515	Drilled Well	-	X
Donnellson	710	Drilled Wells	.070	X
Elkhart	260	Drilled Well	-	X

Appendix 1 (Continued)

Community	Estimated Pop. Served	Source of Supply	Rated Plant Capacity MGD	Average Plant Output MGD
Ellsworth	495	Drilled Wells	.140	X
Fairfield	8,055	Imp. Reservoir & Drilled Well	1.000	X
Fremont	460	Drilled Well	-	X
Gilbert	320	Drilled Well	.170	X
Grinnell	7,365	Deep Wells	1.7	X
Hedrick	760	Drilled Wells	.115	X
Huxley	485	Drilled Wells	-	X
Jewell	1,115	Gravel Packed Wells	.220	X
Kelley	240	Drilled Well	-	X
Kellogg	625	Gravel Packed & Shallow Wells	X	X
Keota	1,095	Drilled Wells	.432	X
Lambs Grove	(235)	Newton	-	-
Libertyville	370	Drilled Well	.144	X
Lockridge	205	Drilled Well	X	X
Lynnville	410	Drilled Well	-	X
McCallsburg	270	Drilled Well	.070	X

Appendix 1 (Continued)

Community	Estimated Pop. Served	Source of Supply	Rated Plant Capacity MGD	Average Plant Output MGD
Maxwell	775	Deep Well	X	X
Melbourne	515	Drilled Well	.070	X
Mingo	260	Gravel Packed Well	.058	X
Monroe	1,365	Drilled Wells	-	X
Montezuma	1,415	Imp. Reservoir /Diamond Lake/	.360	X
Mount Pleasant	7,340	Drilled & Bored Wells	.350	X
Nevada	4,225	Drilled Wells	.864	X
New London	1,695	Drilled Wells	.144	X
New Sharon	1,065	Gravel Packed Wells	.200	X
Oskaloosa	11,055	Wells & South Skunk River	2.880	X
Randall	200	Drilled Well	-	X
Rhodes	360	Drilled Well	.070	X
Roland	750	Shallow & Deep Wells	.317	X
Rose Hill	225	Drilled Well	-	X

Appendix 1 (Continued)

Community	Estimated Pop. Served	Source of Supply	Rated Plant Capacity MGD	Average Plant Output MGD
Searsboro	165	Drilled Well	-	X
Sigourney	2,385	Drilled & Gravel Packed Wells	.720	X
Story City	1,775	Drilled Wells	.720	X
Sully	510	Drilled Well	-	X
Washington	6,035	Drilled Wells	X	X
Wayland	595	Drilled Well	.086	X
Webster	135	Drilled Well	-	X
West Chester	255	Drilled Well	-	X
What Cheer	955	Drilled Wells	.170	X
Winfield	860	Drilled Wells	.216	X

*Indicates column does not apply

**Indicates no information is available

Appendix 2

Water Under Permit
Skunk River
(Acre-Feet Per Year)

	Materials Products*	Power	Food Processing	Manufacturing	Irrigation	Municipal Needs	Recreation	Storage	Air Conditioners	TOTALS
Well Sources										
Total Use	0.0	0.0	329.3	5.5	2816.4	7377.4	455.3	0.0	102.2	11086.2
Resources Depletion**	0.0	0.0	5.3	0.6	2816.4	737.7	4.4	0.0	0.0	3564.4
Source Depletion***	0.0	0.0	329.3	5.5	2816.4	7377.4	455.3	0.0	102.2	11086.2
Stream Sources										
Total Use	10304.0	0.0	0.0	0.0	1326.4	0.0	1175.3	1441.6	0.0	13657.3
Resources Depletion	138.8	0.0	0.0	0.0	1326.4	0.0	10.4	0.0	0.0	885.6
Source Depletion	7765.7	0.0	0.0	0.0	1326.4	0.0	1175.3	0.0	0.0	9677.4
Reservoir Sources										
Total Use	8825.2	0.0	0.0	0.0	0.0	0.0	0.0	3110.2	0.0	11935.4
Resources Depletion	142.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	142.2
Source Depletion	5901.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5901.2
Total Water Under Permit										
	19129.2	0.0	329.3	5.5	3552.8	7377.4	1630.6	4551.8	102.2	36678.9

*Water used to process materials such as sand and gravel.
**Amount of water taken from the water source and consumed.
***Amount of water taken from the water source and not returned to that particular source.

Appendix 3

Municipalities with Sewage Treatment Systems in Skunk River Basin

Community	1960 Population	Estimated Population Served	Discharged to	Type of Treatment	P. E. (BOD) Raw	P. E. (BOD) Discharged
Ames	27,003	26,000	Skunk River	Secondary	27,400	2,740
Baxter	681	600	Prairie Cr. to Skunk River	Lagoons	600E*	60E
Brighton	724	650	Walnut Cr. to Skunk River	Secondary	650E	150E
Colfax	2,331	2,100	Skunk River	Secondary	2,100E	200E
Danville	579	500	Long Creek	Secondary	600E	60E
Donnellson	709	600	Dry Creek to Sugar Creek	Secondary	600E	60E
Elkhart	260	200	Ditch to Skunk R.	Lagoon	200E	20E
Ellsworth	493	300	Skunk River	No Treatment	300	300
Fairfield	8,054	7,300	Crow Cr. to Skunk River	Secondary	8,000E	3,000E
Grinnell	7,367	7,000	Sugar Cr. to North Skunk River	Secondary	7,200E	720E
Huxley	486	400	Ditch to Skunk R.	Secondary	800E	80E
Jewell	1,113	1,000	Skunk River	Lagoon	1,000E	100E

*Estimated

Appendix 3 (Continued)

Community	1960 Population	Estimated Population Served	Discharged to	Type of Treatment	P. E. (BOD) Raw	P. E. (BOD) Discharged
Kellog	623	550	North Skunk River	Secondary	700E	70E
Keota	1,096	1,000	Dutch Cr. to Skunk River	Secondary	1,000E	100E
Lambs Grove	234	200	Cherry Cr. to Skunk River	Secondary	200E	70E
Lynnville	411	350	Ditch to North Skunk River	Lagoon	350E	30E
Maxwell	773	770	Rock Creek	Secondary	700E	100E
Melbourne	517	300	Creek to North Skunk River	Secondary	X	50
Monroe	1,366	1,200	Cr. to Skunk R.	Secondary	1,200E	120E
Montezuma	1,416	1,000	Moon Cr. to North Skunk R.	Secondary	1,000E	100E
Mount Pleasant	7,339	6,500	Saunders Creek	Secondary	6,500E	1,600E
Nevada	4,227	4,000	West Branch of Indian Creek	Secondary	X	X
New London	1,694	1,600	Mud Cr. to Skunk River	Secondary	2,200E	200E
New Sharon	1,063	800	Dry Creek to North Skunk R.	Secondary	800E	100E
Newton Northwest Plant	15,381	1,500	Cherry Creek to Skunk River	Secondary	4,000	400

Appendix 3 (Continued)

Community	1960 Population	Estimated Population Served	Discharged to	Type of Treatment	P. E. (BOD) Raw	P. E. (BOD) Discharged
Oskaloosa North Plant	11,053	5,500	Cr. to Skunk River	Secondary	6,000E	2,000E
Roland	748	600	Bear Creek to Skunk River	Secondary	700E	170E
Sigourney East Plant	2,387	750	Ditch to North Skunk River	Secondary	750E	250E
Sigourney South Plant	-	100	Ditch to North Skunk River	Primary	100E	75E
Sigourney West Plant	-	900	Ditch to North Skunk River	Secondary	1,000E	400E
Story City	1,773	1,300	Skunk River	Secondary	1,300E	400E
Washington	6,037	5,500	West Fork of Crooked Creek	Secondary	10,000E	1,000E
What Cheer	956	800	Coal Creek to North Skunk River	Secondary	800E	300E
Williams	490	400	Cr. to Skunk R.	Secondary	600E	100E
Winfield	862	810	East Fork of Crooked Creek	Secondary	935E	100E
Newton South Plant		7,000	Sewer Creek to Skunk River	Secondary	12,000	2,000
Newton Southwest Plant		6,000	Cherry Creek to Skunk River	Secondary	6,000	1,000

Appendix 4

Calculations for Water Quality Needs

The oxygen sag formula used to determine the flow requirements in order to maintain specific levels of quality was the standard Phelps-Streeter formula. In using this formula, several parameters must be determined. These constants include deoxygenation and reaeration rates, initial saturation of dissolved oxygen, water temperature, and velocity of flow. The following table shows the values used in this study.

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Deoxygenation Constant, K1	1.0	1.0	1.0	1.5	2.4	2.7	3.1	2.8	2.4	2.2	1.0	1.0
Reaeration Constant, K2	4.6	4.6	4.4	3.5	2.7	2.5	2.3	2.4	2.7	2.8	3.7	4.6
Average Temperature ^{o}C	2	3	4	12	21	24	27	25	22	20	10	2

Initial saturation of dissolved oxygen (all months) - 80%

Velocity of Flow (all months) 0.75 feet per second

The assimilation model indicates, when considering that the location of proposed reservoirs are above Ames, Iowa, that the critical section of the river will be located a few miles below Ames. If this condition is satisfied, the rest of the main stem will also have satisfactory conditions.

In order to evaluate the need for low flow augmentation, one should analyze what the conditions would be if no low flow augmentation was provided. Figures 4-1 and 4-2 indicate the dissolved oxygen levels at different occurrence probabilities at the critical point should no low flow augmentation be provided and an 85 percent reduction in BOD is obtained. Figure 4-1 shows for the present conditions, while Figure 4-2 is for conditions as projected to 2070. For example, in 2070, 95 percent of the time in the month of April the quality will be 2 ppm (parts per million) and 80 percent of the time it will be 4 ppm.

When calculating water quality needs, it will be found that different quantities of dilution flow requirements will result by choosing different degrees of treatment of the raw sewage and also by choosing different levels of dissolved oxygen concentration of the treated sewage.

Table 4-1 shows the amount of flow augmentation needed for different sets of conditions for the month of July. This is the most critical month, therefore, all the other months will have lower flow requirements.

July Dilution Requirements Under Different Conditions

Table 4-1

	5 ppm D.O. Goal						4 ppm D.O. Goal					
Year	D.O. in Eff. 1 ppm			D.O. in Eff. 5 ppm			D.O. in Eff. 1 ppm			D.O. in Eff. 5 ppm		
	85*	90*	95*	85	90	95	85	90	95	85	90	95
1970	24**	16	9	22	13	4	17	10	5	15	8	0
1990	33	22	14	29	17	5	23	14	8	20	10	0
2020	37	24	15	32	19	5	25	15	9	21	11	0
2070	46	30	19	40	23	7	31	19	11	27	14	0

*Percent treatment.
**In cubic feet per second.

As can be seen from the table, the flow requirements decrease with increased degree of treatment and amount of reaeration. The range in 2070 goes from 46 cfs (cubic feet per second) for the lower degrees of treatment and effluent aeration to 7 cfs with the highest degree of treatment and effluent aeration, when trying to maintain 5 ppm D.O. at the critical point and 31 cfs to zero when trying to maintain 4 ppm. It can be seen that by providing a high degree of treatment the need for low flow augmentation is essentially eliminated.

Public Law 660 provides that ". . . storage and water releases shall not be provided as a substitute for adequate treatment or other means of controlled water at their source." Quantities of water required for water quality control are computed on the premise that adequate treatment will be provided.

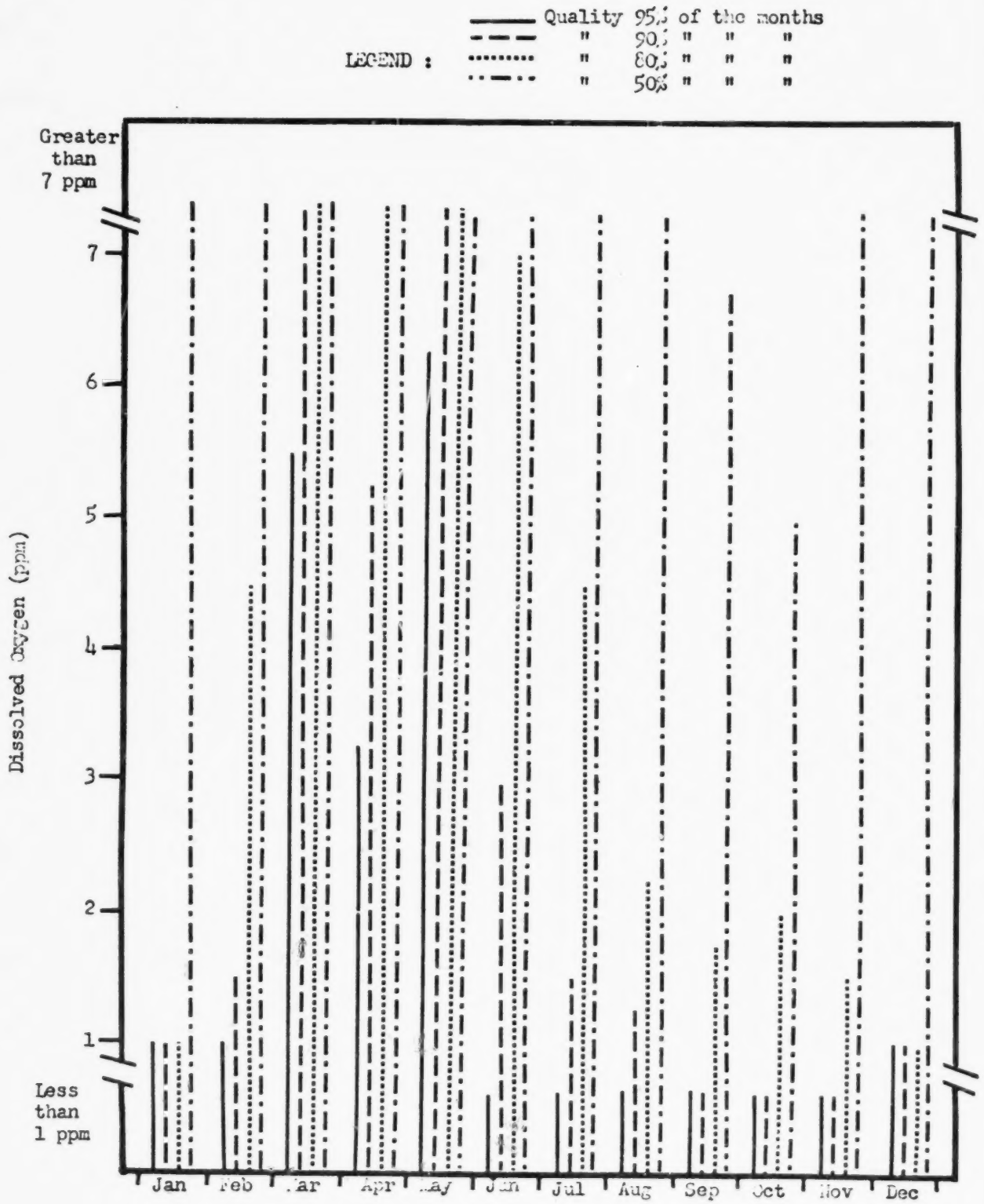
Based on organic removal obtained from well operated biological sewage treatment, it is expected that 90 percent removal of biological oxygen demand (BOD) can be obtained for waste reaching the sewage treatment plant. At the present time, however, urban runoff will be expected to contain waste amounting to about 5 percent of the BOD found in municipal waste and is not generally amenable to economical treatment; therefore, adequate treatment for purposes of evaluation of storage needs is considered as 85 percent removal of BOD from the collected wastes.

Using 85 percent treatment, Figure 4-3 shows the relationship which exists between flow augmentation and dissolved oxygen at the critical point for July, the month which requires the highest amount or flow augmentation. It can be seen that flow requirements to maintain a

constant quality increase quite rapidly for the first 20 years of projection as compared with the following years. For example, to maintain a 5 ppm quality level requires 24 cfs presently, but will have increased to 33 cfs by 1990.

The flow requirements to maintain higher dissolved oxygen concentrations increase rapidly at the higher levels. For example, only 5 cfs more will increase the dissolved oxygen concentration from 2 ppm to 3 ppm in the year 2020, but to go from 4 ppm to 5 ppm requires 12 cfs more, and to go from 5 ppm to 6.4 ppm requires 39 cfs more.

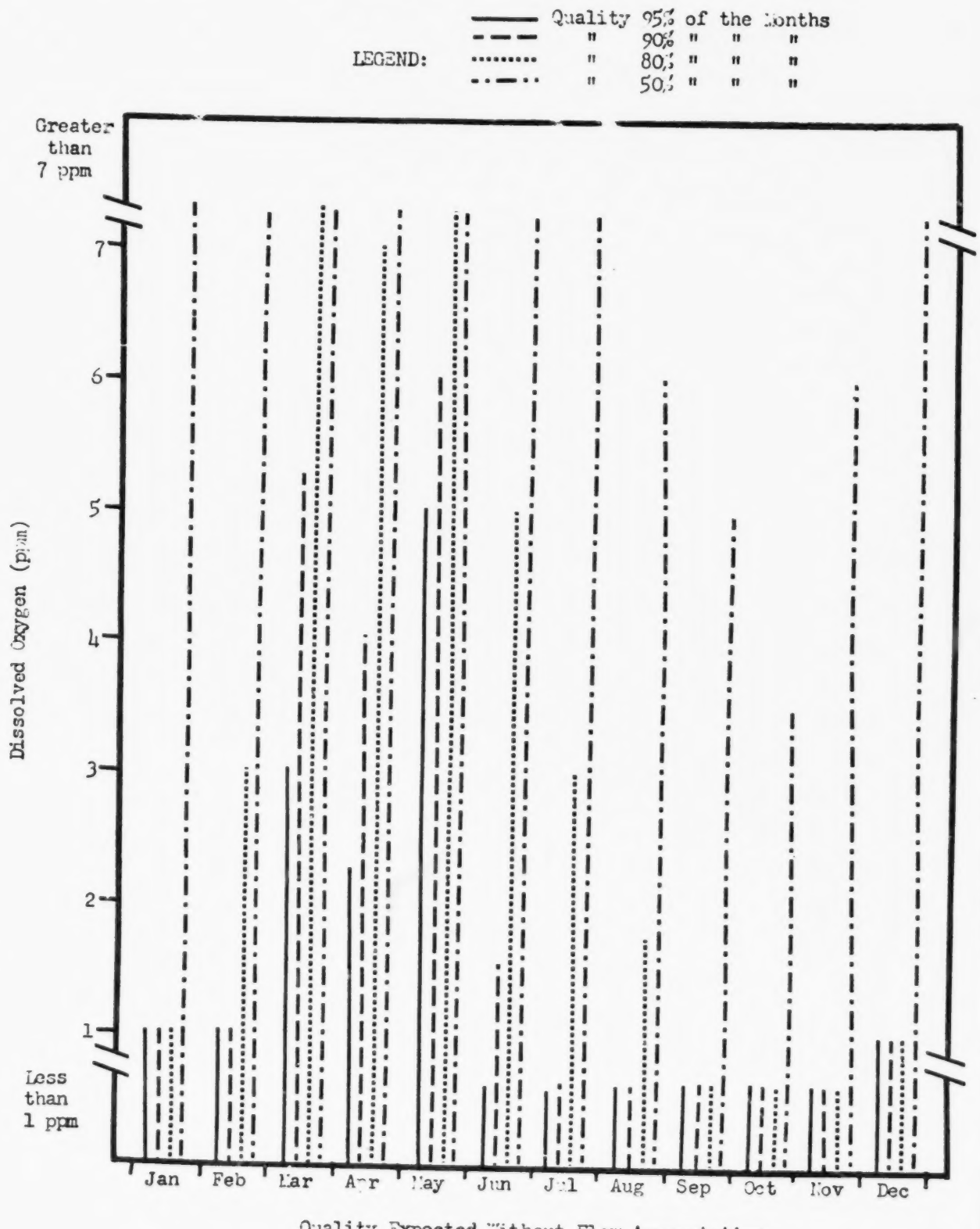
Also, shown on the graph is the flow which occurs 80 percent of the month and 90 percent of the month. Therefore, it can be seen that for most of the years without any flow augmentation a quality level of 3 ppm or better could be maintained for 80 percent of the month of July.



Quality Expected Without Flow Augmentation

1970 Conditions

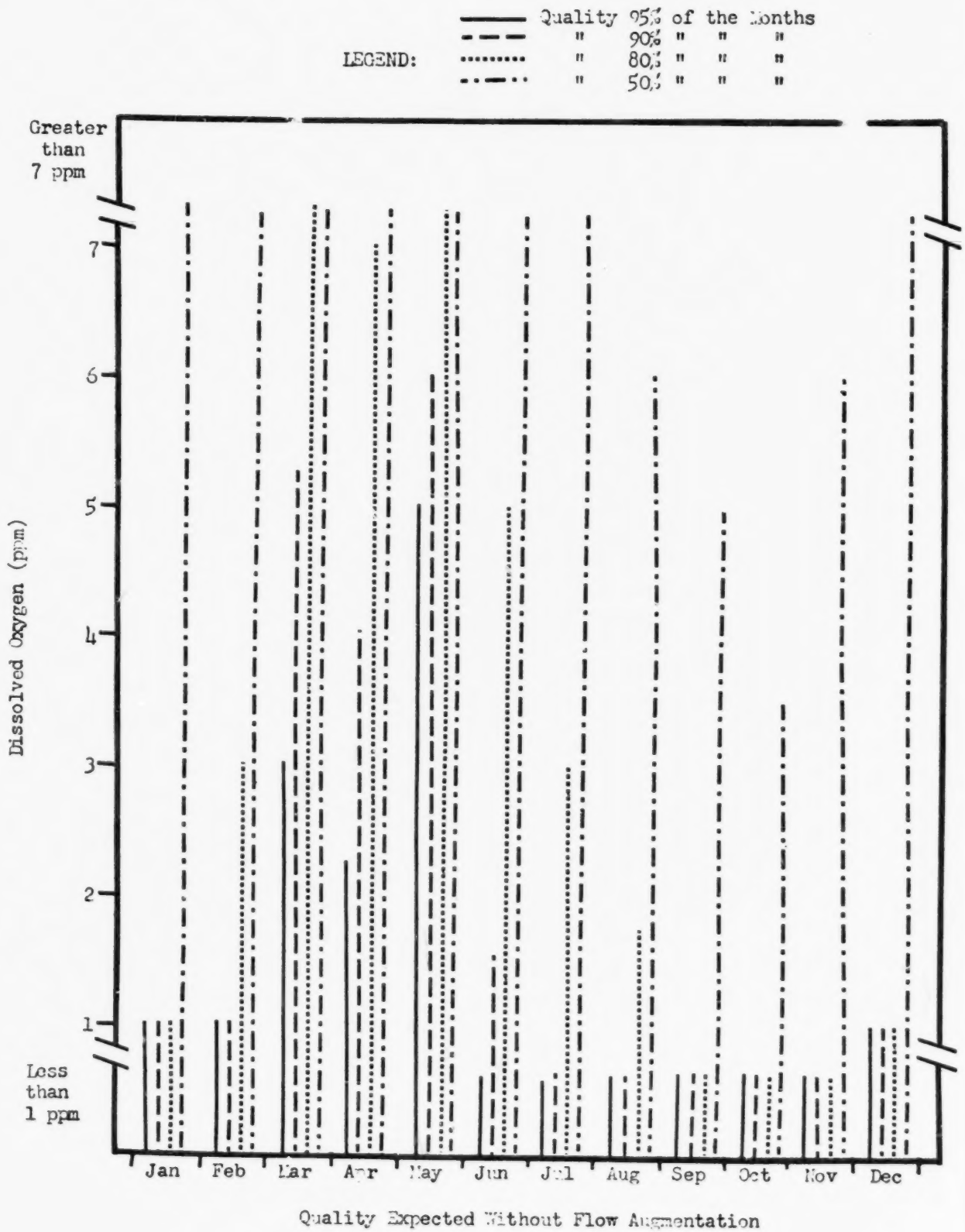
FIGURE 4-1



Quality Expected Without Flow Augmentation

2070 Conditions

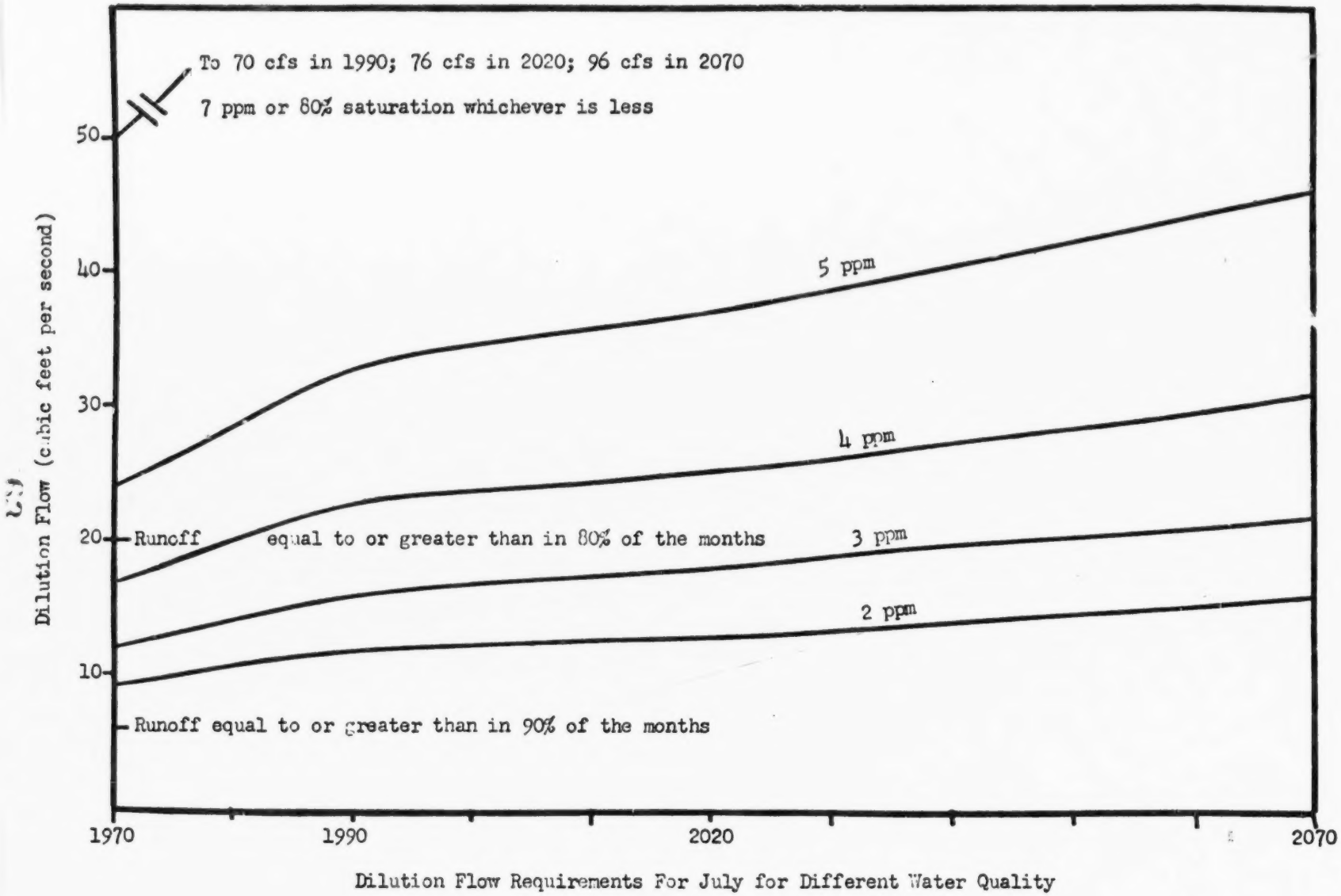
FIGURE 4-2



Quality Expected Without Flow Augmentation

2070 Conditions

FIGURE 4-2



Dilution Flow Requirements For July for Different Water Quality

FIGURE 4-3

Appendix 5

Effect of Storage on Water Quality

Different quantities of storage will by proper management provide varying levels of water quality control. The presentation in this Appendix will help to indicate the effect of storage on water quality.

When analyzing water quality it is necessary to think of it in terms of probability of failure, since the means required to insure against complete non-failure would be extreme and impracticable. Figures 5-1, -2, -3, present the relationship between supplemental flow in terms of volume and quality obtainable at different probabilities of failure. They are given for conditions in the years 1970, 2020 and 2070. As an example, in the year 2020 a supplemental flow of 3,800 acre-feet will maintain a quality of 4 mg/l of dissolved oxygen for 90 percent of the years. However, by doubling this storage a quality of 5 mg/l of dissolved oxygen can be maintained for 96 percent of the years.

As noted, the amount of supplemental flow required will increase as the basin develops and the waste loads increase. Figure 5-4 shows this increase in storage requirements of future years. This shows at a 90 percent probability of assurance that in order to maintain a quality level of 5 mg/l there is required a storage of 3,400 acre-feet in 1970 and this increases to 8,000 acre-feet by the year 2070. It can be noted that it a storage of only 3,400 acre-feet were provided, which

would allow an attainment of 5 mg/l with a 90 percent assurance in 1970, by the year 2070 this quality will have dropped to 2.5 mg/l at the same probability level. However, the 5 mg/l concentration will still be attainable at a 50 percent probability of assurance, as shown in Figure 5-3. Also shown in Figure 5-4 is the storage requirement that is needed to maintain 5 mg/l of dissolved oxygen with a 95 percent assurance and an 80 percent assurance of attainment.

Another way of looking at the relation of quality versus storage, would be as shown in Figure 5-5, which shows the hypothetical quality if a supplemental flow of 5,000 acre-feet is provided. As can be noted, the quality can be maintained at 5 mg/l in the year 1970 with a protection level of 95 percent of the years, but drops to 80 percent of the years in the year 2070.

The reservoir operation as it affects reservoir levels is of importance in the propagation of fish life. Figure 5-6 shows the effect on reservoir levels which results from operating 250 years of synthetic flow, using the queuing theory. As can be noted, the reservoir is between 80 to 100 percent full most of the time. Also shown as a contrast is the percentage of time the reservoir is empty to 20 percent full. As can be seen, this percentage is very low.

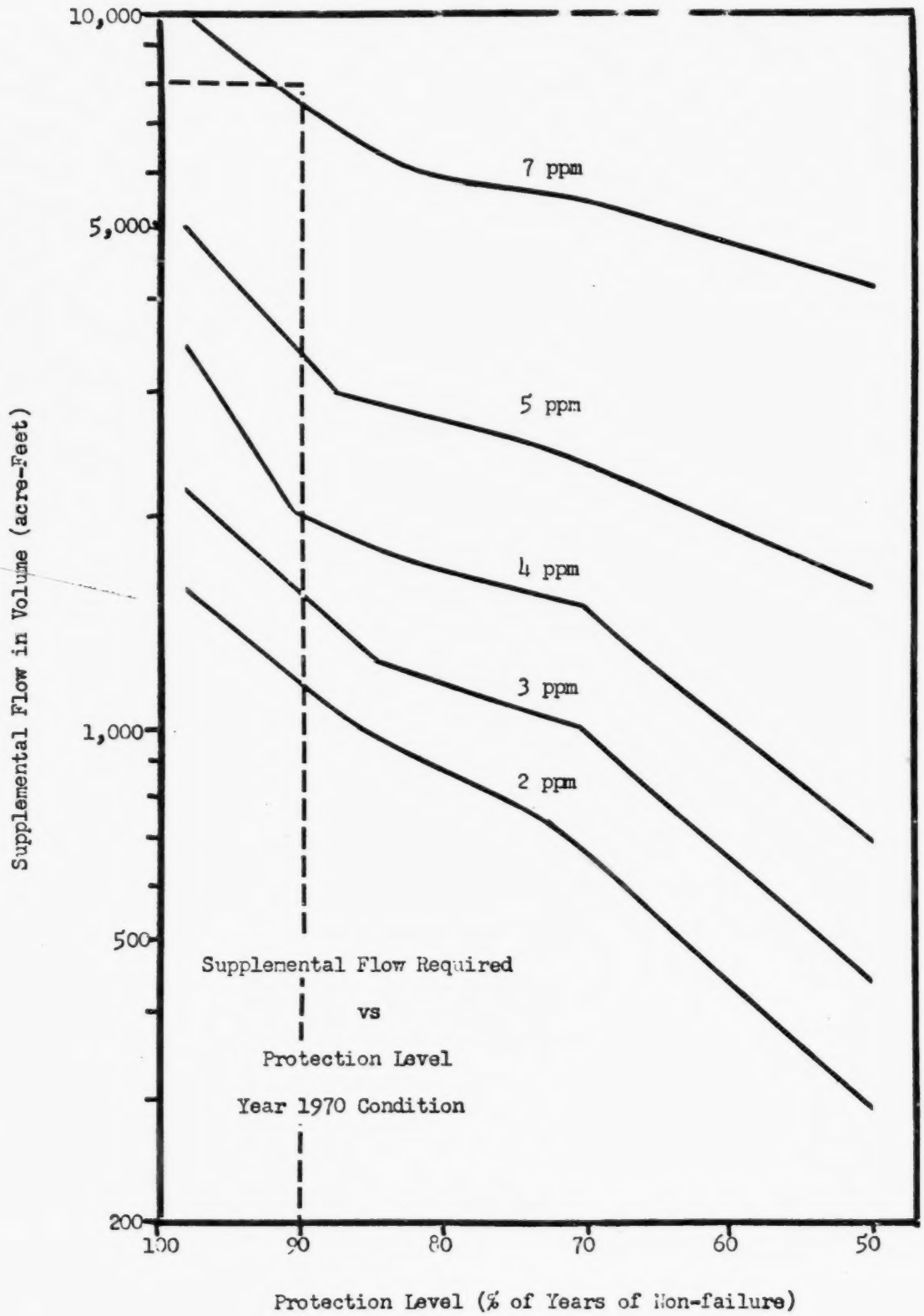

10,000
5,000
1,000
500
200
7 ppm
5 ppm
4 ppm
3 ppm
2 ppm
Supplemental Flow in Volume (acre-Feet)
Supplemental Flow Required
vs
Protection Level
Year 1970 Condition
100
90
80
70
60
50
Protection Level (% of Years of Non-failure)

FIGURE 5-1

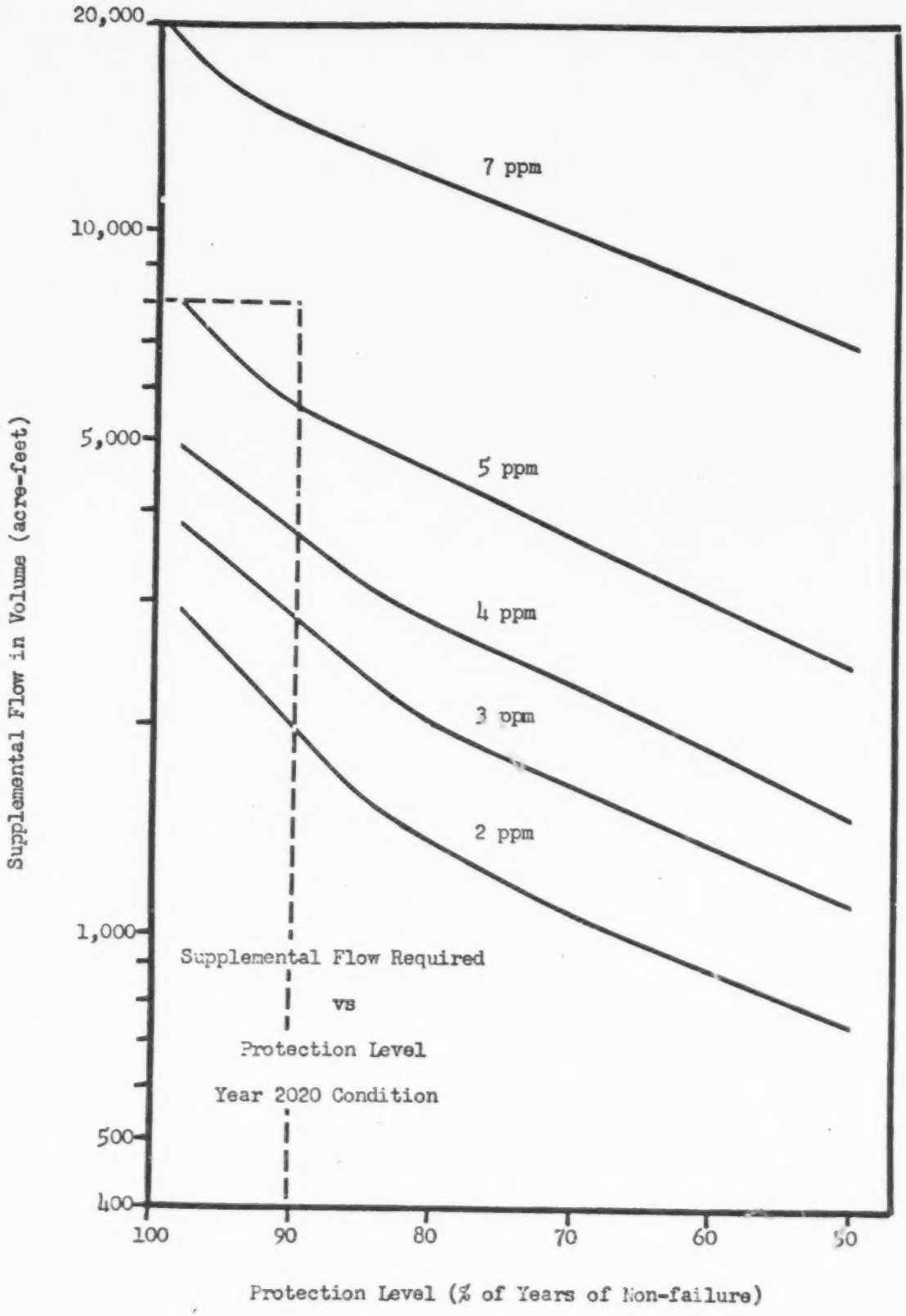

20,000
10,000
5,000
1,000
500
400
7 ppm
5 ppm
4 ppm
3 ppm
2 ppm
Supplemental Flow Required
vs
Protection Level
Year 2020 Condition
100
90
80
70
60
50
Supplemental Flow in Volume (acre-feet)
Protection Level (% of Years of Non-failure)

FIGURE 5-2

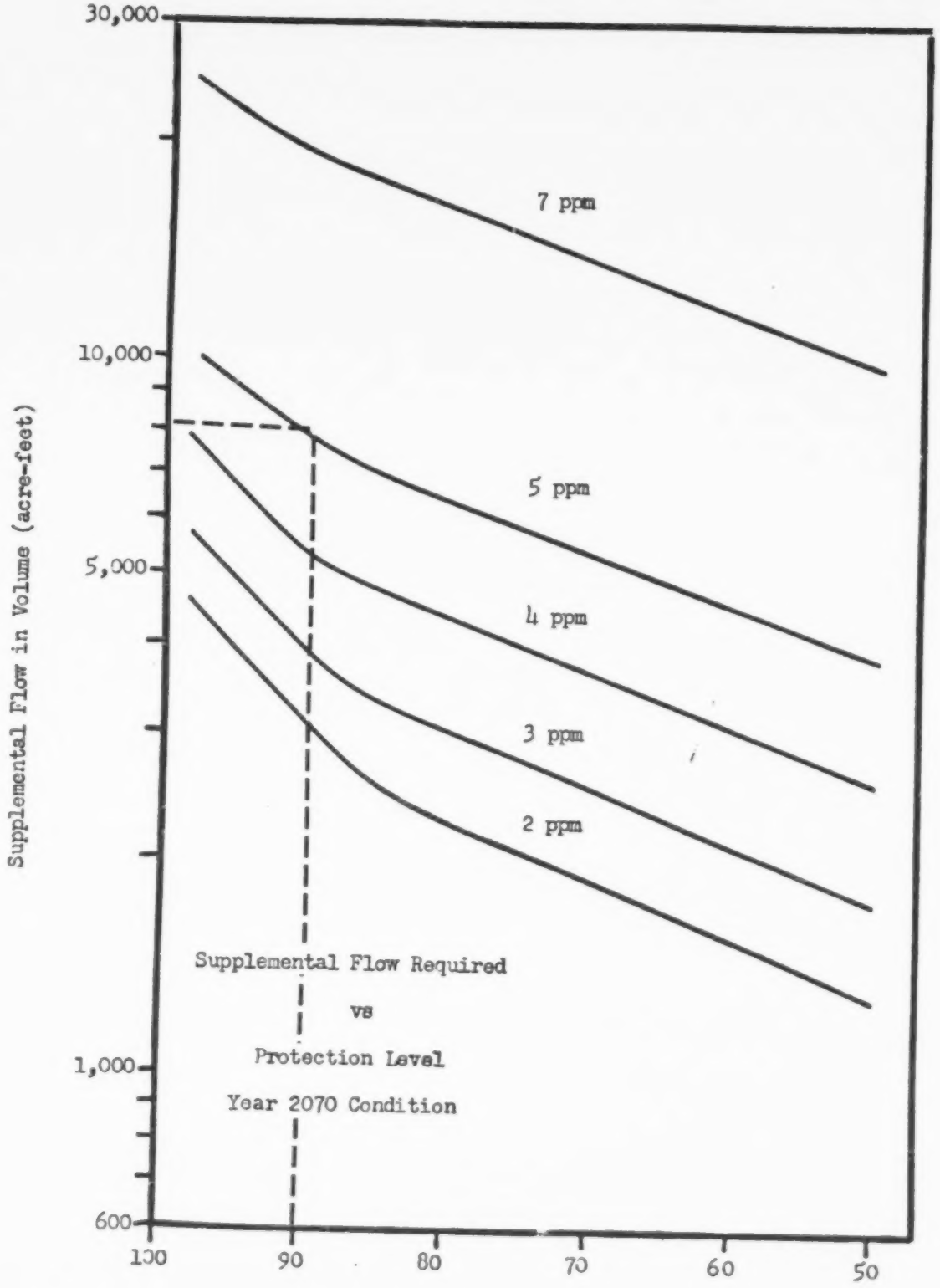

30,000
10,000
5,000
1,000
600
7 ppm
5 ppm
4 ppm
3 ppm
2 ppm
Supplemental Flow Required
vs
Protection Level
Year 2070 Condition
100
90
80
70
60
50
Supplemental Flow in Volume (acre-feet)
Protection Level (% of Years of Non-failure)

FIGURE 5-3

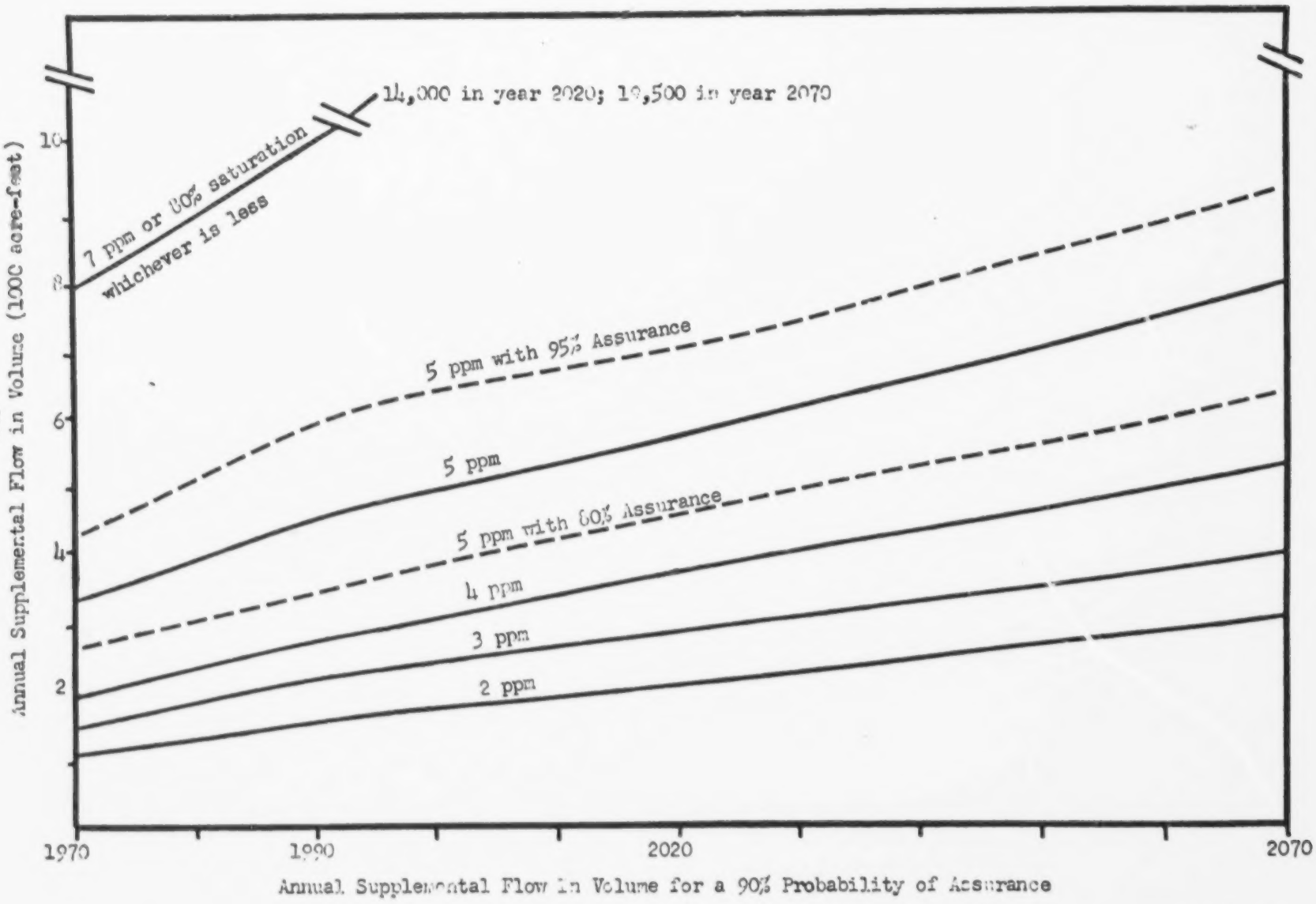
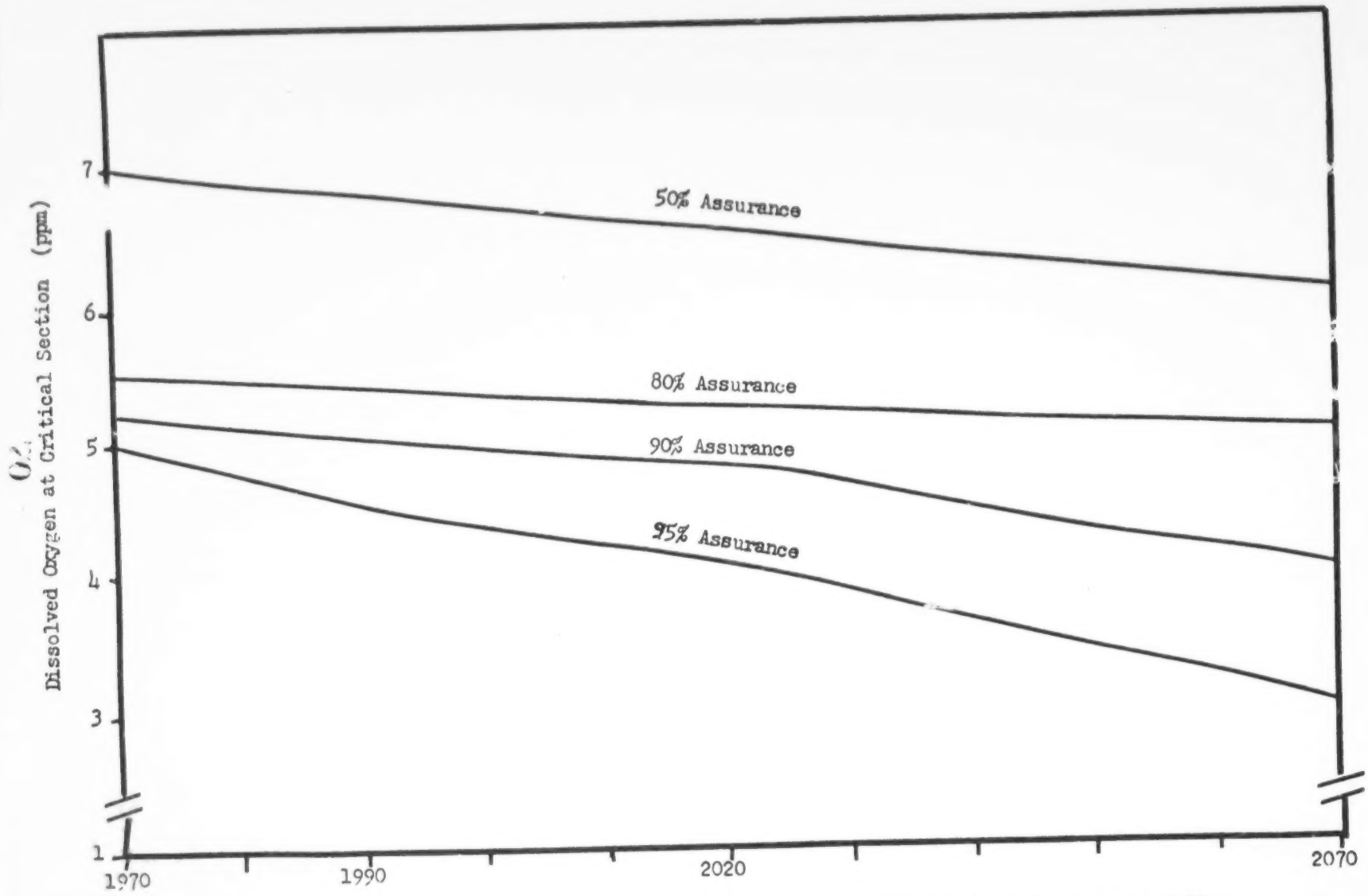

14,000 in year 2020; 19,500 in year 2070
7 ppm or 80% saturation whichever is less
5 ppm with 95% Assurance
5 ppm
5 ppm with 80% Assurance
4 ppm
3 ppm
2 ppm
Annual Supplemental Flow in Volume (1000 acre-feet)
10
8
6
4
2
1970
1990
2020
2070
Annual Supplemental Flow in Volume for a 90% Probability of Assurance

FIGURE 5-4



Water Quality at Different Probability Levels Resulting from 5000 Acre-Feet of Supplementary Flow

FIGURE 5-5

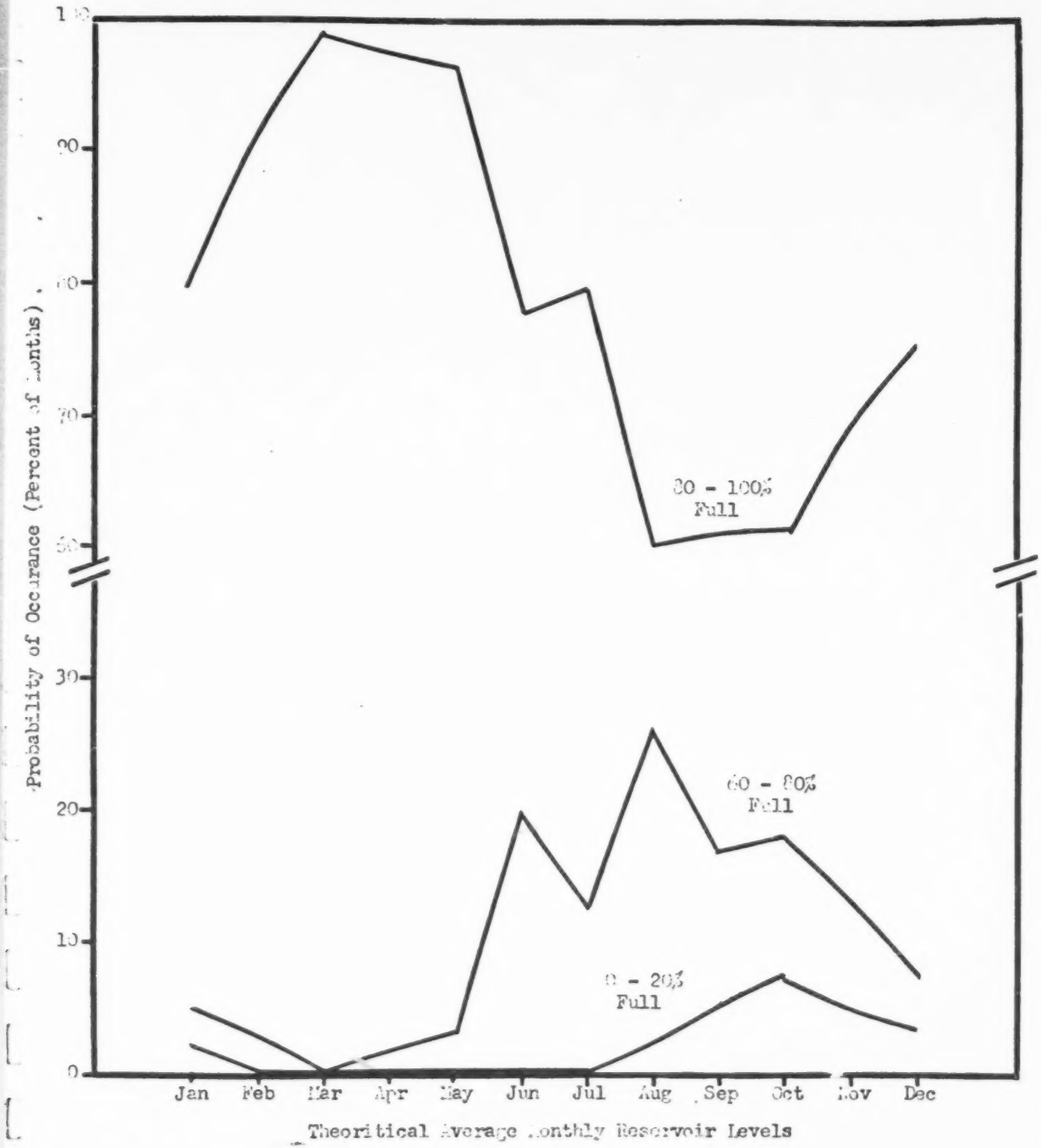
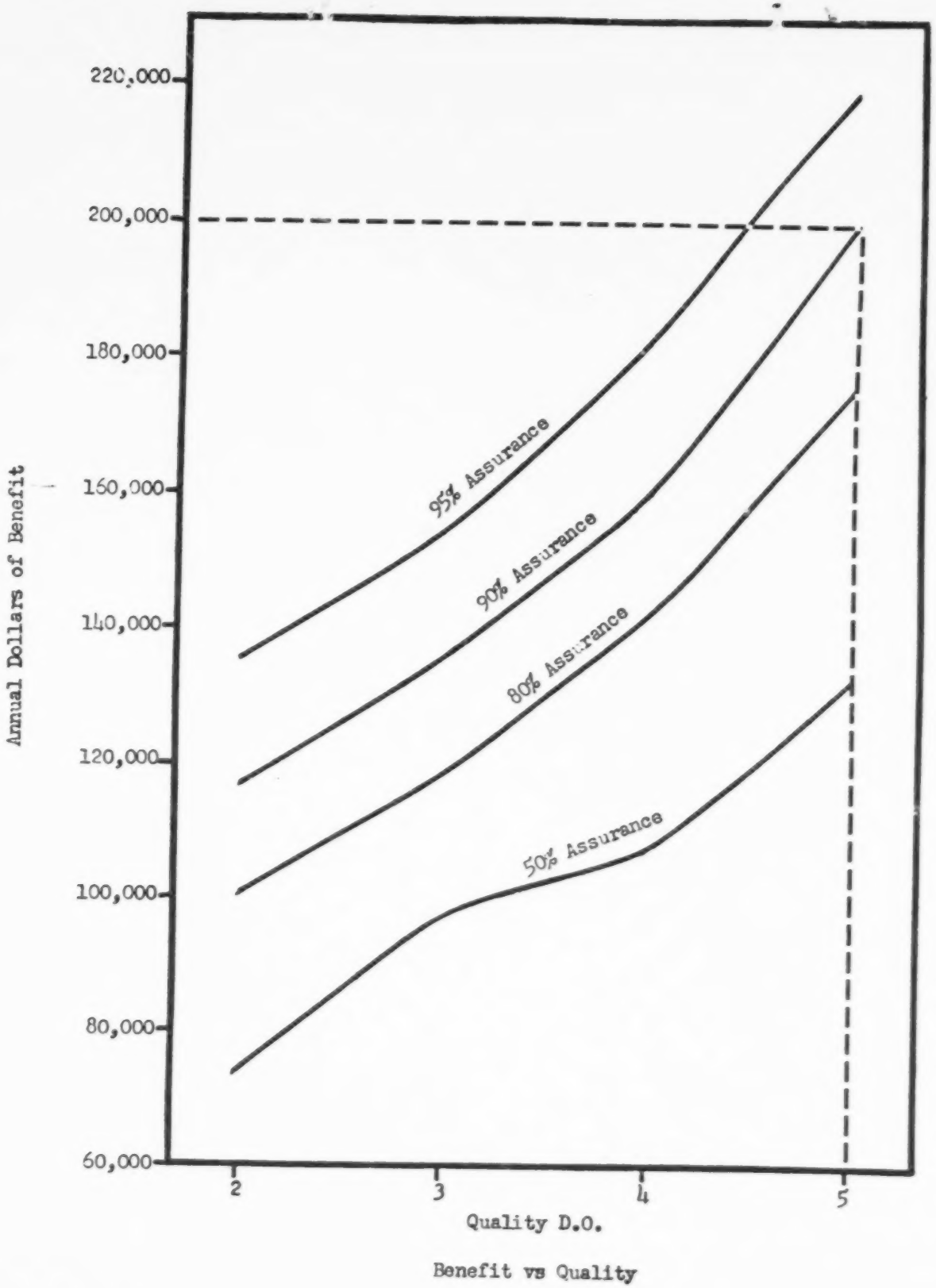

Probability of Occurance (Percent of Months)
80 - 100% Full
60 - 80% Full
0 - 20% Full
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Theoritical Average Monthly Reservoir Levels

FIGURE 5-6

Appendix 6

Evaluation of Water Quality Benefits

As indicated within the report, the benefits are widespread and do not lend themselves to direct evaluation. One approach to describing these benefits quantitatively is by evaluating the cost or attaining the desired quality by the most feasible method. This was determined to be a single-purpose reservoir. Figure 6-1 shows the benefits as determined based on a single-purpose reservoir for different quality levels and different levels of protection. The quality levels shown are those to be attained in the year 2070 and, therefore, the quality will be higher for the proceeding years as noted in this report. The dotted line shows the point at which the value of benefits for the recommended quality was determined.



Benefit vs Quality

FIGURE 6-1

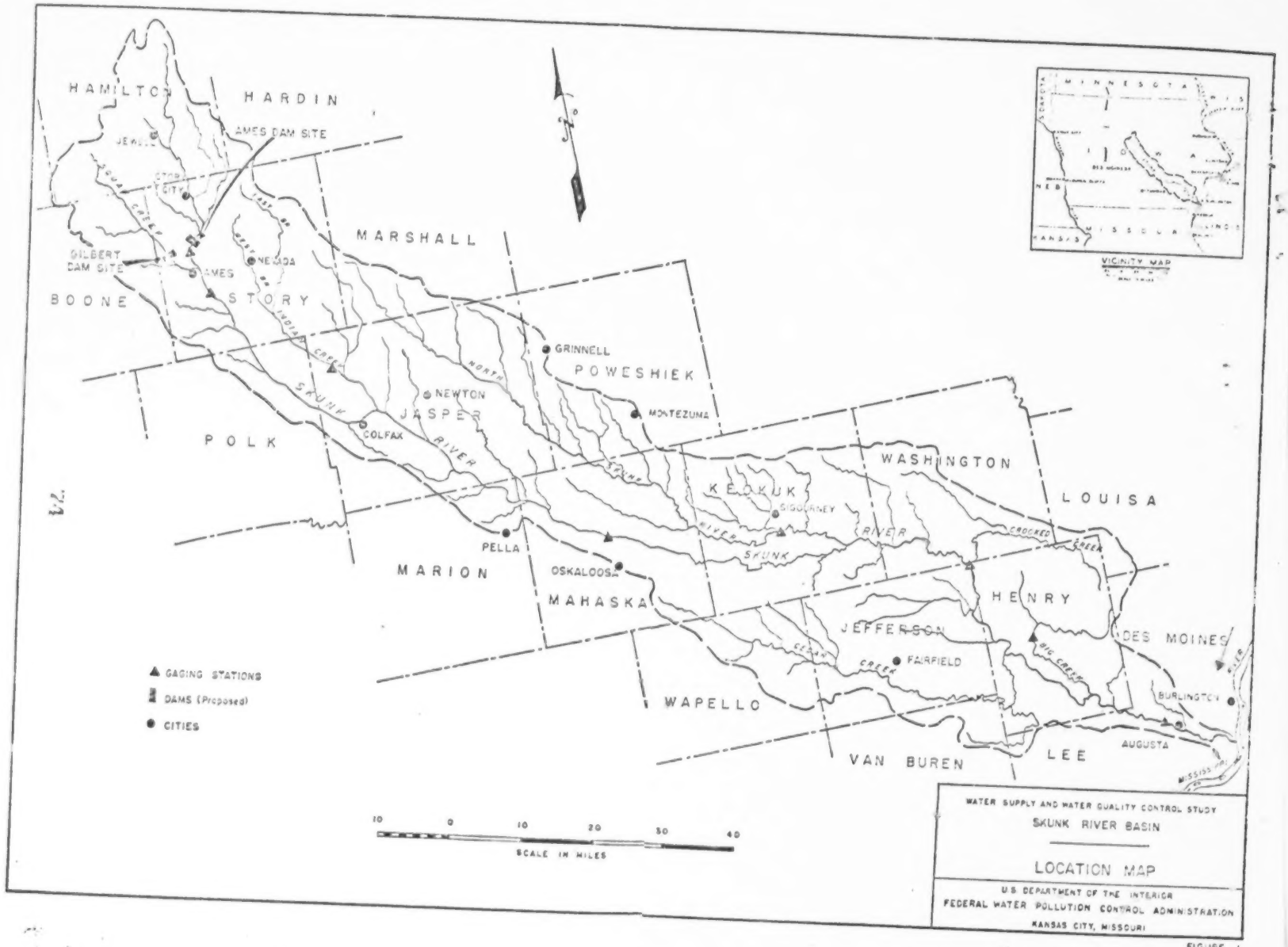

HAMILTON
HARDIN
AMES DAM SITE
JEWELL
STORY CITY
SQUAW CREEK
GILBERT DAM SITE
AMES
NEVADA
MARSHALL
BOONE
STORY
INDIAN CREEK
SKUNK RIVER
NORTH
GRINNELL
POWESHIEK
NEWTON
JASPER
MONTEZUMA
POLK
COLFAX
KEOKUK
WASHINGTON
LOUISA
SIGOURNEY
CROOKED CREEK
PELLA
MARION
OSKALOOSA
MAHASKA
HENRY
JEFFERSON
DES MOINES
BIG CREEK
FAIRFIELD
WAPELLO
BURLINGTON
AUGUSTA
VAN BUREN
LEE
GAGING STATIONS
DAMS (Proposed)
CITIES
10 0 10 20 30 40
SCALE IN MILES
MINNESOTA
VICINITY MAP
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
SKUNK RIVER BASIN
LOCATION MAP
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
KANSAS CITY, MISSOURI

FIGURE 1